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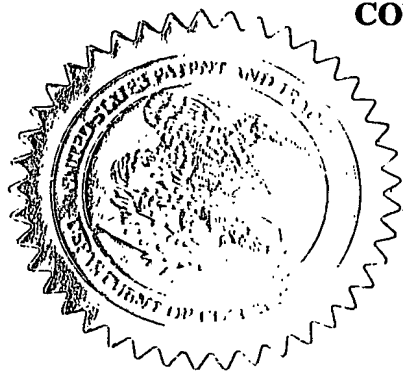
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FILING DATE.**

**APPLICATION NUMBER: 60/459,716**

**FILING DATE: April 02, 2003**

**RELATED PCT APPLICATION NUMBER: PCT/US04/10094**

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Honeywell Docket No. Not Yet Assigned (4015)  
Practitioner's Docket No. 54-009-001

PATENT  
JC971 U.S. PTO  
60/459716

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Ignatius RASIAH; and Nancy DEAN

For: THERMAL INTERCONNECT AND INTERFACE SYSTEMS, METHODS OF PRODUCTION  
AND USES THEREOF

Box Provisional Patent Application  
Assistant Commissioner for Patents  
Washington, D.C. 20231

COVER SHEET FOR FILING PROVISIONAL APPLICATION  
(37 C.F.R. SECTION 1.51(c)(1))

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 C.F.R. section 1.51(c)(1)(i). The following comprises the information required by 37 C.F.R. Section 1.51(c)(1):

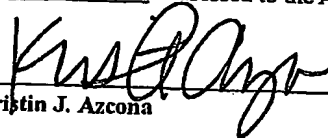
1. The names of the inventors are (37 C.F.R. Section 1.51(c)(1)(ii)):
  1. Ignatius RASIAH
  2. Nancy DEAN
2. Residence addresses of the inventors, as numbered above (37 C.F.R. Section 1.51(c)(1)(iii)):
  1. 17 Changi Business Park Central i  
Singapore 486073

CERTIFICATION UNDER 37 C.F.R. SECTION 1.10\*

(Express Mail label number is mandatory.)

(Express Mail certification is optional.)

I hereby certify that this correspondence and the documents referred to as attached therein are being deposited with the United States Postal Service on April 1, 2003, in an envelope as "EXPRESS MAIL POST OFFICE TO ADDRESSEE" service under 37 C.F.R. Section 1.10, Mailing Label Number 4156740637206 addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231.

  
Kristin J. Azcona

2. 1827 S. Liberty Drive  
Liberty Lake, WA 99019

3. The title of the invention is (37 C.F.R. Section 1.51(c)(1)(iv)):

**THERMAL INTERCONNECT AND INTERFACE SYSTEMS, METHODS OF  
PRODUCTION AND USES THEREOF**

4. The name, registration, customer and telephone numbers of the practitioner are (37 C.F.R. Section 1.51(c)(1)(v)):

Name of practitioner: Sandra P. Thompson  
Reg. No. 46264  
Tel. No. 714-433-2622

5. The docket number used to identify this application is (37 C.F.R. Section 1.51(c)(1)(vi)):

Docket No. 54-009-001

6. The correspondence address for this application is (37 C.F.R. Section 1.51(c)(1)(vii)):

Sandra P. Thompson  
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Costa Mesa, CA 92626

7. Statement as to whether invention was made by an agency of the U.S. Government or under contract with an agency of the U.S. Government. (37 C.F.R. Section 1.51(c)(1)(viii)).

This invention was NOT made by an agency of the United States Government, or under contract with an agency of the United States Government.

8. Identification of documents accompanying this cover sheet:

A. Documents required by 37 C.F.R. Section 1.51(c)(2)-(3):

Specification:	No. of pages	41
Drawings:	No. of sheets	21

**B. Additional documents:**

Claims:                      No. of claims    0

**9.     Fee**

The filing fee for this provisional application, as set in 37 C.F.R. Section 1.16(k), is \$160.00 for other than a small entity.

**10.    Fee payment**

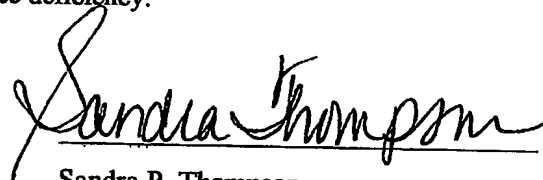
Fee payment in the amount of \$160.00 is being made at this time.

**11.    Method of fee payment**

Check in the amount of \$160.00.

Please charge Account No. 501367 for any fee deficiency.

Date: April 1, 2003



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Honeywell Docket No.: Not Assigned (4015)  
Riordan Docket No.: 54-009-001

**THERMAL INTERCONNECT AND INTERFACE SYSTEMS,  
METHODS OF PRODUCTION AND USES THEREOF**

**FIELD OF THE INVENTION**

5       The field of the invention is thermal interconnect systems, thermal interface systems and interface materials in electronic components, semiconductor components and other related layered materials applications.

**BACKGROUND**

10       Electronic components are used in ever increasing numbers in consumer and commercial electronic products. Examples of some of these consumer and commercial products are televisions, personal computers, Internet servers, cell phones, pagers, palm-type organizers, portable radios, car stereos, or remote controls. As the demand for these consumer and commercial electronics increases, there is also a demand for those same products to become  
15 smaller, more functional, and more portable for consumers and businesses.

As a result of the size decrease in these products, the components that comprise the products must also become smaller. Examples of some of those components that need to be reduced in size or scaled down are printed circuit or wiring boards, resistors, wiring, keyboards, touch pads, and chip packaging. Products and components also need to be prepackaged, such  
20 that the product and/or component can perform several related or unrelated functions and tasks. Examples of some of these "total solution" components and products comprise layered materials, mother boards, cellular and wireless phones and telecommunications devices and other components and products, such as those found in US Patent and PCT Application Serial Nos.: 60/396294 filed July 15, 2002, 60/294433 filed May 30, 2001 and PCT/US02/17331 filed May  
25 30, 2002, which are all commonly owned and incorporated herein in their entirety.

Components, therefore, are being broken down and investigated to determine if there are better building materials and methods that will allow them to be scaled down and/or combined to accommodate the demands for smaller electronic components. In layered components, one goal appears to be decreasing the number of the layers while at the same time increasing the functionality and durability of the remaining layers. This task can be difficult, however, given that several of the layers and components of the layers should generally be present in order to operate the device.

Also, as electronic devices become smaller and operate at higher speeds, energy emitted in the form of heat increases dramatically. A popular practice in the industry is to use thermal grease, or grease-like materials, alone or on a carrier in such devices to transfer the excess heat dissipated across physical interfaces. Most common types of thermal interface materials are thermal greases, phase change materials, and elastomer tapes. Thermal greases or phase change materials have lower thermal resistance than elastomer tape because of the ability to be spread in very thin layers and provide intimate contact between adjacent surfaces. Typical thermal impedance values range between  $0.2-1.6^{\circ}\text{C cm}^2/\text{W}$ . However, a serious drawback of thermal grease is that thermal performance deteriorates significantly after thermal cycling, such as from  $-65^{\circ}\text{C}$  to  $150^{\circ}\text{C}$ , or after power cycling when used in VLSI chips. It has also been found that the performance of these materials deteriorates when large deviations from surface planarity causes gaps to form between the mating surfaces in the electronic devices or when large gaps between mating surfaces are present for other reasons, such as manufacturing tolerances, etc. When the heat transferability of these materials breaks down, the performance of the electronic device in which they are used is adversely affected.

Thus, there is a continuing need to: a) design and produce thermal interface materials, layered materials, components and products that meet customer specifications while minimizing the size of the device and number of layers; b) produce more efficient and better designed materials, products and/or components with respect to the compatibility requirements of the material, component or finished product; c) develop reliable methods of producing desired thermal interface materials and layered materials and components/products comprising contemplated thermal interface and layered materials; and d) effectively reduce the number of

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production steps necessary for a package assembly, which in turn results in a lower cost of ownership over other conventional layered materials and processes.

# SUMMARY

Pre-attached/pre-assembled thermal solutions and/or IC (interconnect) packages are provided herein that comprise one or more components of a suite of thermal interface materials that exhibit low thermal resistance for a wide variety of interface conditions and demands. Thermal interface materials may comprise PCM45, which is a high conductivity phase change material manufactured by Honeywell Electronic Materials™, or metal and metal-based base materials also manufactured by Honeywell Electronic Materials™, such as solders, connected to Ni, Cu, Al and AlSiC, which are classified as heat spreaders or those materials that work to dissipate heat.

Layered interface materials described herein comprise at least one crosslinkable thermal interface component and at least one heat spreader component coupled to the thermal interface component. A method of forming contemplated layered interface materials comprises: a) providing a crosslinkable thermal interface component; b) providing a heat spreader component; and c) physically coupling the thermal interface component and the heat spreader component. At least one additional layer, including a substrate layer, can be coupled to the layered interface material.

A constituent of layered interface materials described herein comprises at least one crosslinkable thermal interface component that is produced by combining at least one rubber compound, at least one amine resin and at least one thermally conductive filler. This contemplated thermal interface component takes on the form of a liquid or "soft gel". The gel state is brought about through a crosslinking reaction between the at least one rubber compound composition and the at least one amine resin composition. More specifically, the amine resin is incorporated into the rubber composition to crosslink the primary hydroxyl groups on the rubber compounds thus forming the soft gel phase. Therefore, it is contemplated that at least some of the rubber compounds will comprise at least one terminal hydroxyl group.

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5 Amine or amine-based resins are added or incorporated into the rubber composition or mixture and/or combination of rubber compounds primarily to facilitate a crosslinking reaction between the amine resin and the primary or terminal hydroxyl groups on at least one of the rubber compounds. The crosslinking reaction between the amine resin and the rubber compounds leads to a "soft gel" phase to the mixture, instead of a liquid state.

10 Once the thermal interface component composition that comprises at least one rubber compound, at least one amine resin, and at least one thermally conductive filler has been prepared, the composition must be compared to the needs of the electronic component, vendor, or electronic product to determine whether a phase change material is needed to change some of the physical properties of the composition.

15 Phase change materials are useful in thermal interface component applications because they store and release heat as they oscillate between solid and liquid form. A phase change material gives off heat as it changes to a solid state, and as it returns to a liquid, it absorbs heat. The phase change temperature is the melting temperature at which the heat absorption and rejection takes place. Phase change materials are also useful in that they may be preapplied as a solid, but then change phase and exhibit the beneficial grease-like performance characteristics at operating temperatures.

20 A method for forming the crosslinkable thermal interface components disclosed herein comprises a) providing at least one saturated rubber compound, b) providing at least one amine resin, c) crosslinking the at least one saturated rubber compound and the at least one amine resin to form a crosslinked rubber-resin mixture, d) adding at least one thermally conductive filler to the crosslinked rubber-resin mixture, and e) adding a wetting agent to the crosslinked rubber-resin mixture. This method can also further comprise adding at least one phase change material to the crosslinked rubber-resin mixture.

25 A method for forming the thermal solution/package and/or IC package disclosed herein comprises a) providing at least one thermal interface component and/or material coupled to at least one heat spreader component and/or material; b) providing at least one adhesive interface; c) providing at least one surface or substrate; d) coupling the at least one thermal interface



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component and/or material with the at least one adhesive interface to form an adhesive unit; e) coupling the adhesive unit to the at least one surface or substrate to form a thermal package; f) optionally coupling an additional layer or component to the thermal package.

5 A suitable interface material can also be produced that comprises a resin mixture and at least one solder material. The resin material may comprise any suitable resin material, but it is preferred that the resin material be silicone-based comprising one or more compounds such as vinyl silicone, vinyl Q resin, hydride functional siloxane and platinum-vinylsiloxane. The solder material may comprise any suitable solder material or metal, such as indium, silver, copper, aluminum, tin, lead, bismuth, gallium and alloys thereof, silver coated copper, and silver coated  
10 aluminum, but it is preferred that the solder material comprise indium or indium-based compounds. Suitable interface materials may also comprise metal flakes or sintered metal flakes.

A contemplated thermal interface component can be provided as a dispensable liquid paste to be applied by dispensing methods and then cured as desired. It can also be provided as a  
15 highly compliant, cured, elastomer film or sheet for pre-application on interface surfaces or on other materials, such as heat sinks, substrates, and/or a compliant fibrous interface material or component. It can further be provided and produced as a soft gel or liquid that can be applied to surfaces by any suitable dispensing method, such as screen printing or ink jet printing. Even further, the material can be provided as a tape that can be applied directly to interface surfaces,  
20 substrates, compliant fibrous interface materials or component and/or electronic components. Additionally and as mentioned, the material can be provided with at least one adhesive component, such as an adhesive tape, adhesive film or other adhesive material, to facilitate the process and/or method of coupling the thermal interface material with a surface and/or substrate.

Heat spreader components or heat spreading components (heat spreader and heat  
25 spreading are used herein interchangeably and have the same common meaning) generally comprise a metal or metal-based base material, such as nickel, aluminum, copper. Geometrical features, such as a truncated pyramidal section, which reduce stresses may be beneficial when utilizing high modulus thermal interface materials. Alternatively, lower coefficient of thermal expansion materials, such as CuSiC or AlSiC and/or other materials, such as diamond and

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composite-based materials, which may or may not include metal or metal-based base materials may be used. The composite-based materials may also comprise carbon fibers and other similar materials. Heat spreader components are generally designed to dissipate heat. Specific examples of contemplated heat spreader components are shown under the Examples section.

5 Applications of the contemplated thermal solutions, IC Packages, layered interface materials, thermal interface components and heat spreader components described herein comprise incorporating the materials into a layered material, a layered component, an electronic component, a semiconductor component, a finished electronic product or a finished semiconductor product.

10 Various objects, features, aspects and advantages of the present disclosure will become more apparent from the following detailed description of preferred embodiments of the invention.

### Detailed Description

15 A suitable interface material or component should conform to the mating surfaces ("wets" the surface), possess a low bulk thermal resistance and possess a low contact resistance. Bulk thermal resistance can be expressed as a function of the material's or component's thickness, thermal conductivity and area. Contact resistance is a measure of how well a material or component is able to make contact with a mating surface, layer or substrate. The thermal  
 20 resistance of an interface material or component can be shown as follows:

$$\Theta_{\text{interface}} = t/kA + 2\Theta_{\text{contact}} \quad \text{Equation 1}$$

where  $\Theta$  is the thermal resistance,

t is the material thickness,

25 k is the thermal conductivity of the material

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A is the area of the interface

The term " $t/kA$ " represents the thermal resistance of the bulk material and " $2\theta_{\text{contact}}$ " represents the thermal contact resistance at the two surfaces. A suitable interface material or component should have a low bulk resistance and a low contact resistance, i.e. at the mating surface.

Many electronic and semiconductor applications require that the interface material or component accommodate deviations from surface flatness resulting from manufacturing and/or warpage of components because of coefficient of thermal expansion (CTE) mismatches.

A material with a low value for  $k$ , such as thermal grease, performs well if the interface is thin, i.e. the " $t$ " value is low. If the interface thickness increases by as little as 0.002 inches, the thermal performance can drop dramatically. Also, for such applications, differences in CTE between the mating components causes the gap to expand and contract with each temperature or power cycle. This variation of the interface thickness can cause pumping of fluid interface materials (such as grease) away from the interface.

Interfaces with a larger area are more prone to deviations from surface planarity as manufactured. To optimize thermal performance, the interface material should be able to conform to non-planar surfaces and thereby lower contact resistance.

Optimal interface materials and/or components possess a high thermal conductivity and a high mechanical compliance, e.g. will yield elastically when force is applied. High thermal conductivity reduces the first term of Equation 1 while high mechanical compliance reduces the second term. The layered interface materials and the individual components of the layered interface materials described herein accomplish these goals. When properly produced, the thermal interface component described herein will span the distance between the mating surface of the heat spreader material and the silicon die component thereby allowing a continuous high conductivity path from one surface to the other surface.

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Pre-attached/pre-assembled thermal solutions and/or IC (interconnect) packages comprise one or more components of the thermal interface materials described herein and at least one adhesive component. Several of the contemplated pre-attached/pre-assembled thermal solutions/IC Packages are shown in Figures 1, 10, 12, 14 and 17-24. It should be understood that there are many other embodiments that are contemplated and that can be assembled given the disclosure presented herein. These thermal interface materials exhibit low thermal resistance for a wide variety of interface conditions and demands. As used herein, the term "adhesive component" means any substance, inorganic or organic, natural or synthetic, that is capable of bonding other substances together by surface attachment. In some embodiments, the adhesive component may be added to or mixed with the thermal interface material, may actually be the thermal interface material or may be coupled, but not mixed, with the thermal interface material. Examples of some adhesive components comprise double-sided tape from SONY, such as SONY T4411, 3M F9460PC or SONY T4100D203.

A method for forming the thermal solution/package and/or IC package disclosed herein comprises a) providing at least one thermal interface component and/or material or a layered interface material; b) providing at least one adhesive interface; c) providing at least one surface or substrate; d) coupling the at least one thermal interface component and/or material with the at least one adhesive interface to form an adhesive unit; e) coupling the adhesive unit to the at least one surface or substrate to form a thermal package; f) optionally coupling an additional layer or component to the thermal package.

These thermal solutions and/or IC packages may also comprise layered interface materials. Layered interface materials described herein comprise at least one crosslinkable thermal interface component and at least one heat spreader component coupled to the thermal interface component. A method of forming contemplated layered interface materials comprises: a) providing a crosslinkable thermal interface component; b) providing a heat spreader component; and c) physically coupling the thermal interface component and the heat spreader component. At least one additional layer may be coupled with the layered interface material described herein. The at least one additional layer can comprise another interface material, a surface, a substrate, an adhesive, a compliant fibrous component or any other suitable layer.

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A contemplated crosslinkable thermal interface component is produced by combining at least one rubber compound, at least one amine resin and at least one thermally conductive filler. This contemplated interface material takes on the form of a liquid or "soft gel". As used herein, "soft gel" means a colloid in which the disperse phase has combined with the continuous phase to form a viscous "jelly-like" product. The gel state or soft gel state of the thermal interface component is brought about through a crosslinking reaction between the at least one rubber compound composition and the at least one amine resin composition. More specifically, the amine resin is incorporated into the rubber composition to crosslink the primary hydroxyl groups on the rubber compounds, thus forming the soft gel phase. Therefore, it is contemplated that at least some of the rubber compounds will comprise at least one terminal hydroxyl group. As used herein, the phrase "hydroxyl group" means the univalent group  $-OH$  occurring in many inorganic and organic compounds that ionize in solution to yield  $OH$  radicals. Also, the "hydroxyl group" is the characteristic group of alcohols. As used herein, the phrase "primary hydroxyl groups" means that the hydroxyl groups are in the terminal position on the molecule or compound. Rubber compounds contemplated herein may also comprise additional secondary, tertiary, or otherwise internal hydroxyl groups that could also undergo a crosslinking reaction with the amine resin. This additional crosslinking may be desirable depending on the final gel state needed for the product or component in which the gel is to be incorporated.

It is contemplated that the rubber compounds could be "self-crosslinkable" in that they could crosslink intermolecularly with other rubber compounds or intramolecularly with themselves, depending on the other components of the composition. It is also contemplated that the rubber compounds could be crosslinked by the amine resin compounds and perform some self-crosslinking activity with themselves or other rubber compounds.

In preferred embodiments, the rubber compositions or compounds utilized can be either saturated or unsaturated. Saturated rubber compounds are preferred in this application because they are less sensitive to thermal oxidation degradation. Examples of saturated rubbers that may be used are ethylene-propylene rubbers (EPR, EPDM), polyethylene/butylene, polyethylene-butylene-styrene, polyethylene-propylene-styrene, hydrogenated polyalkyldiene "mono-ols" (such as hydrogenated polybutadiene mono-ol, hydrogenated polypropadiene mono-ol,

hydrogenated polypentadiene mono-ol), hydrogenated polyalkyldiene "diols" (such as hydrogenated polybutadiene diol, hydrogenated polypropadiene diol, hydrogenated polypentadiene diol) and hydrogenated polyisoprene. However, if the compound is unsaturated, it is most preferred that the compound undergo a hydrogenation process to rupture or remove at least some of the double bonds. As used herein, the phrase "hydrogenation process" means that an unsaturated organic compound is reacted with hydrogen by either a direct addition of hydrogen to some or all of the double bonds, resulting in a saturated product (addition hydrogenation), or by rupturing the double bond entirely, whereby the fragments further react with hydrogen (hydrogenolysis). Examples of unsaturated rubbers and rubber compounds are polybutadiene, polyisoprene, polystyrene-butadiene and other unsaturated rubbers, rubber compounds or mixtures/combinations of rubber compounds.

As used herein, the term "compliant" encompasses the property of a material or a component that is yielding and formable, especially at about room temperature, as opposed to solid and unyielding at room temperature. As used herein, the term "crosslinkable" refers to those materials or compounds that are not yet crosslinked.

As used herein, the term "crosslinking" refers to a process in which at least two molecules, or two portions of a long molecule, are joined together by a chemical interaction. Such interactions may occur in many different ways including formation of a covalent bond, formation of hydrogen bonds, hydrophobic, hydrophilic, ionic or electrostatic interaction. Furthermore, molecular interaction may also be characterized by an at least temporary physical connection between a molecule and itself or between two or more molecules.

More than one rubber compound of each type may be combined to produce a crosslinkable thermal interface component; however, it is contemplated that in the preferred thermal interface component, at least one of the rubber compounds or constituents will be a saturated compound. Olefin-containing or unsaturated thermal interface components, with appropriate thermal fillers, exhibit a thermal capability of less than  $0.5 \text{ cm}^2 \text{ }^\circ\text{C/W}$ . Unlike thermal grease, thermal performance of the thermal interface component will not degrade after thermal cycling or flow cycling in IC devices because liquid olefins and liquid olefin mixtures (such as those comprising amine resins) will crosslink to form a soft gel upon heat activation.

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Moreover, when applied as a thermal interface component, it will not be "squeezed out" as thermal grease does in use and will not display interfacial delamination during thermal cycling.

Amine or amine-based resins are added or incorporated into the rubber composition or mixture of rubber compounds primarily to facilitate a crosslinking reaction between the amine resin and the primary or terminal hydroxyl groups on at least one of the rubber compounds. The crosslinking reaction between the amine resin and the rubber compounds produces a "soft gel" phase in the mixture, instead of a liquid state. The degree of crosslinking between the amine resin and the rubber composition and/or between the rubber compounds themselves will determine the consistency of the soft gel. For example, if the amine resin and the rubber compounds undergo a minimal amount of crosslinking (10% of the sites available for crosslinking are actually used in the crosslinking reaction) then the soft gel will be more "liquid-like". However, if the amine resin and the rubber compounds undergo a significant amount of crosslinking (40-60% of the sites available for crosslinking are actually used in the crosslinking reaction and possibly there is a measurable degree of intermolecular or intramolecular crosslinking between the rubber compounds themselves) then the gel would become thicker and more "solid-like".

Amine and amino resins are those resins that comprise at least one amine substituent group on any part of the resin backbone. Amine and amino resins are also synthetic resins derived from the reaction of urea, thiourea, melamine or allied compounds with aldehydes, particularly formaldehyde. Typical and contemplated amine resins are primary amine resins, secondary amine resins, tertiary amine resins, glycidyl amine epoxy resins, alkoxybenzyl amine resins, epoxy amine resins, melamine resins, alkylated melamine resins, and melamine-acrylic resins. Melamine resins are particularly useful and preferred in several contemplated embodiments described herein because a) they are ring-based compounds, whereby the ring contains three carbon and three nitrogen atoms, b) they can combine easily with other compounds and molecules through condensation reactions, c) they can react with other molecules and compounds to facilitate chain growth and crosslinking, d) they are more water resistant and heat resistant than urea resins, e) they can be used as water-soluble syrups or as insoluble powders dispersible in water, and f) they have high melting points (greater than 325°C

and are relatively non-flammable). Alkylated melamine resins, such as butylated melamine resins, propylated melamine resins, pentylated melamine resins hexylated melamine resins and the like, are formed by incorporating alkyl alcohols during the resin formation. These resins are soluble in paint and enamel solvents and in surface coatings.

5 Thermal filler particles to be dispersed in the thermal interface component or mixture should advantageously have a high thermal conductivity. Suitable filler materials include metals, such as silver, copper, aluminum, and alloys thereof, and other compounds, such as boron nitride, aluminum nitride, silver coated copper, silver-coated aluminum, conductive polymers and carbon fibers. Combinations of boron nitride and silver or boron nitride and silver/copper  
10 also provide enhanced thermal conductivity. Boron nitride in amounts of at least 20 wt.% and silver in amounts of at least about 60 wt % are particularly useful. Preferably, fillers with a thermal conductivity of greater than about 20 and most preferably at least about 40 W/m°C can be used. Optimally, it is desired to have a filler of not less than about 80 W/m°C thermal conductivity.

15 As used herein, the term "metal" means those elements that are in the d-block and f-block of the Periodic Chart of the Elements, along with those elements that have metal-like properties, such as silicon and germanium. As used herein, the phrase "d-block" means those elements that have electrons filling the 3d, 4d, 5d, and 6d orbitals surrounding the nucleus of the element. As used herein, the phrase "f-block" means those elements that have electrons filling the 4f and 5f  
20 orbitals surrounding the nucleus of the element, including the lanthanides and the actinides. Preferred metals include indium, silver, copper, aluminum, tin, bismuth, lead, gallium and alloys thereof, silver coated copper, and silver coated aluminum. The term "metal" also includes alloys, metal/metal composites, metal ceramic composites, metal polymer composites, as well as other metal composites. As used herein, the term "compound" means a substance with constant  
25 composition that can be broken down into elements by chemical processes.

Of special efficacy is a filler comprising a particular form of carbon fiber referred to as "vapor grown carbon fiber" (VGCF), such as is available from Applied Sciences, Inc., Cedarville, Ohio. VGCF, or "carbon micro fibers", are highly graphized types by heat treatment (thermal conductivity=1900 W/m°C). Addition of about 0.5 wt. % carbon micro fibers provides



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significantly increased thermal conductivity. Such fibers are available in varying lengths and diameters; namely, 1 millimeter (mm) to tens of centimeters (cm) length and from under 0.1 to over 100  $\mu\text{m}$  in diameter. One useful form of VGCF has a diameter of not greater than about 1  $\mu\text{m}$  and a length of about 50 to 100  $\mu\text{m}$ , and possess a thermal conductivity of about two or three times greater than with other common carbon fibers having diameters greater than 5  $\mu\text{m}$ .

It is difficult to incorporate large amounts of VGCF in polymer systems and interface components and systems, such as the hydrogenated rubber and resin combination already discussed. When carbon microfibers, e.g. (about 1  $\mu\text{m}$ , or less) are added to the polymer they do not mix well, primarily because a large amount of fiber must be added to the polymer to obtain any significant beneficial improvement in thermal conductivity. However, we have discovered that relatively large amounts of carbon microfibers can be added to polymer systems that have relatively large amounts of other conventional fillers. A greater amount of carbon microfibers can be added to the polymer when added with other fibers, which can be added alone to the polymer, thus providing a greater benefit with respect to improving thermal conductivity of the thermal interface component. Desirably, the ratio of carbon microfibers to polymer is in the range of 0.05 to 0.50 by weight.

Once the thermal interface component that comprises at least one rubber compound, at least one amine resin, and at least one thermally conductive filler has been prepared, the composition must be compared to the needs of the electronic component, vendor, or electronic product to determine if an additional phase change material is needed to change some of the physical properties of the composition. Specifically, if the needs of the component or product require that the composition or interface material be in a "soft gel" form or a somewhat liquid form, then an additional phase change material may not need to be added. However, if the component, layered material or product requires that the composition or material be more like a solid, then at least one phase change material should be added.

Phase-change materials that are contemplated herein comprise waxes, polymer waxes or mixtures thereof, such as paraffin wax. Paraffin waxes are a mixture of solid hydrocarbons having the general formula  $\text{C}_n\text{H}_{2n+2}$  and having melting points in the range of about 20°C to 100°C. Examples of some contemplated melting points are about 45°C and 60°C. Thermal

interface components that have melting points in this range are PCM45 and PCM60HD – both manufactured by Honeywell Electronic Materials™. Polymer waxes are typically polyethylene waxes, polypropylene waxes, and have a range of melting points from about 40°C to 160°C.

PCM45 comprises a thermal conductivity of about 3.0 W/mK, a thermal resistance of about 0.25°Ccm<sup>2</sup>/W (0.0038°Ccm<sup>2</sup>/W), is typically applied at a thickness of about 0.0015 inches (0.04 mm) and comprises a typical softness of about 5 to 30 psi (plastically flow under). Typical characteristics of PCM45 are a) a super high packaging density – over 80%, b) a conductive filler, c) extremely low thermal resistance, and as mentioned earlier d) about a 45° phase change temperature. PCM60HD comprises a thermal conductivity of about 5.0 W/mK, a thermal resistance of about 0.17°Ccm<sup>2</sup>/W (0.0028°Ccm<sup>2</sup>/W), is typically applied at a thickness of about 0.0015 inches (0.04 mm) and comprises a typical softness of about 5 to 30 psi (plastically flow under). Typical characteristics of PCM60HD are a) a super high packaging density – over 80%, b) a conductive filler, c) extremely low thermal resistance, and as mentioned earlier d) about a 60° phase change temperature. TM350 (a thermal interface component not comprising a phase change material and manufactured by Honeywell Electronic Materials™) comprises a thermal conductivity of about 3.0 W/mK, a thermal resistance of about 0.25°Ccm<sup>2</sup>/W (0.0038°Ccm<sup>2</sup>/W), is typically applied at a thickness of about 0.0015 inches (0.04 mm) and comprises a typical softness of about 5 to 30 psi (plastically flow under). Typical characteristics of TM350 are a) a super high packaging density – over 80%, b) a conductive filler, c) extremely low thermal resistance, d) about a 125° curing temperature, and e) dispensable non-silicone-based thermal gel.

Phase change materials are useful in thermal interface component applications because they store and release heat as they oscillate between solid and liquid form. As a phase change material changes to a solid state, it gives off heat. As it returns to a liquid, it absorbs heat. The phase change temperature is the melting temperature at which the heat absorption and rejection takes place.

Paraffin-based phase change materials, however, have several drawbacks. On their own, they can be very fragile and difficult to handle. They also tend to squeeze out of a gap from the

device in which they are applied during thermal cycling, very much like grease. The rubber-resin modified paraffin polymer wax system described herein avoids these problems and provides significantly improved ease of handling, is capable of being produced in flexible tape or solid layer form, and does not pump out or exude under pressure. Although the rubber-resin-wax mixtures may have the same or nearly the same temperature, their melt viscosity is much higher and they do not migrate easily. Moreover, the rubber-wax-resin mixture can be designed to be self-crosslinking, which ensures elimination of the pump-out problem in certain applications. Examples of contemplated phase change materials are malenized paraffin wax, polyethylene-maleic anhydride wax, and polypropylene-maleic anhydride wax. The rubber-resin-wax mixtures will functionally form at a temperature between about 50 to 150°C to form a crosslinked rubber-resin network.

It is also advantageous to incorporate additional fillers, substances or particles, such as filler particles, wetting agents or antioxidants into the thermal interface component. Substantially spherical filler particles can be added to the thermal interface component to maximize packing density. Additionally, substantially spherical shapes or the like will provide some control of the thickness during compaction. Typical particle sizes useful for fillers in the rubber material may be in the range of about 1-20  $\mu\text{m}$ , about 21-40  $\mu\text{m}$ , about 41-60  $\mu\text{m}$ , about 61-80  $\mu\text{m}$ , and about 81-100  $\mu\text{m}$  with a maximum of about 100  $\mu\text{m}$ .

Dispersion of filler particles can be facilitated by addition of functional organometallic coupling agents or "wetting" agents, such as organosilane, organotitanate, organozirconium, etc. Organotitanate acts a wetting enhancer to reduce paste viscosity and to increase filler loading. An organotitanate that can be used is isopropyl triisostearyl titanate. The general structure of organotitanate is  $\text{RO-Ti}(\text{OXRY})$  where RO is a hydrolyzable group, and X and Y are binder functional groups.

Antioxidants may also be added to inhibit oxidation and thermal degradation of the cured rubber gel or solid thermal interface component. Typical useful antioxidants include Irganox 1076, a phenol type or Irganox 565, an amine type, (at 0.01% to about 1 wt. %), available from Ciba Giegy of Hawthorne, N.Y. Typical cure accelerators include tertiary amines such as didecylanethylamine, (at 50 ppm--0.5 wt. %).

At least one catalyst may also be added to the thermal interface component in order to promote a crosslinking or chain reaction between the at least one rubber compound, the at least one amine resin, the at least one phase change material, or all three. As used herein, the term "catalyst" means that substance or condition that notably affects the rate of a chemical reaction without itself being consumed or undergoing a chemical change. Catalysts may be inorganic, organic, or a combination of organic groups and metal halides. Although they are not substances, light and heat can also act as catalysts. In contemplated embodiments, the catalyst is an acid. In preferred embodiments, the catalyst is an organic acid, such as carboxylic, acetic, formic, benzoic, salicylic, dicarboxylic, oxalic, phthalic, sebacic, adipic, oleic, palmitic, stearic, phenylstearic, amino acids and sulfonic acid.

A method for forming the crosslinkable thermal interface components disclosed herein comprises a) providing at least one saturated rubber compound, b) providing at least one amine resin, c) crosslinking the at least one saturated rubber compound and the at least one amine resin to form a crosslinked rubber-resin mixture, d) adding at least one thermally conductive filler to the crosslinked rubber-resin mixture, and e) adding a wetting agent to the crosslinked rubber-resin mixture. This method can also further comprise adding at least one phase change material to the crosslinked rubber-resin mixture. As discussed herein, liquid and solid thermal interface components can be formed using the contemplated method, along with tapes, electronic components, semiconductor components, layered materials and electronic and semiconductor products.

The contemplated thermal interface component can be provided as a dispensable liquid paste to be applied by dispensing methods (such as screen printing or stenciling) and then cured as desired. It can also be provided as a highly compliant, cured, elastomer film or sheet for pre-application on interface surfaces, such as heat sinks. It can further be provided and produced as a soft gel or liquid that can be applied to surfaces by any suitable dispensing method, such as screen-printing or ink jet printing. Even further, the thermal interface component can be provided as a tape that can be applied directly to interface surfaces or electronic components.

To illustrate several embodiments of the thermal interface components, a number of examples were prepared by mixing the components described in Examples A through F. As

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indicated in the tables, the properties of the compositions including viscosity, product form, thermal impedance, modulus of elasticity, and thermal conductivity are also reported.

5 The examples shown include one or more of the optional additions, e.g., antioxidant, wetability enhancer, curing accelerators, viscosity reducing agents and crosslinking aids. The amounts of such additions may vary but, generally, they may be usefully present in the following approximate amounts (in wt. %): filler up to 95% of total (filler plus rubbers); wetability enhancer 0.1 to 1% (of total); antioxidant 0.01 to 1% (of total); curing accelerator 50 ppm-0.5% (of total); viscosity reducing agents 0.2-15%; and crosslinking aids 0.1-2%. It should be noted the addition at least about 0.5% carbon fiber significantly increases thermal conductivity.

Composition (by wt %)	A	B	C	D	E	F
Hydrogenated polybutylene mono-ol	7.5	6.3	10	11.33	5	18
Hydrogenated polybutadiene diol	none	none	2	none	none	none
Paraffin Wax	3.1	2.2	none	none	none	none
Alkylated melamine resin (butylated)	1.7	0.4	1.33	2	1	4
Organotitanate	1.5	1.0	6.67	6.67	4	8
Sulfonic Acid Catalyst	0.1	none	none	none	none	none
Phenolic Antioxidant	0.1	0.1	none	none	none	none
Aluminum powder	86	90	80	80	none	none
Silver Powder	none	none	none	none	90	none
Boron Nitride	none	none	none	none	none	70
Product Form	Tape	Tape	Liquid	Liquid	Liquid	Liquid
Thermal Impedance (oC cm2/w)	0.25	0.18	0.25	0.25	0.3	0.35
Thermal conductivity (w.m/oC)	3.0	5.0	2.8	2.8	2.3	2.0
Modulus of Elasticity, Pa	300000	270000	500000	300000	280000	270000
Viscosity, Pa.s	N/A	N/A	200	160	150	220

5 Another suitable interface material can also be produced/prepared that comprises a resin mixture and at least one solder material. The resin material may comprise any suitable resin material, but it is preferred that the resin material be silicone-based comprising one or more compounds such as vinyl silicone, vinyl Q resin, hydride functional siloxane and platinum-

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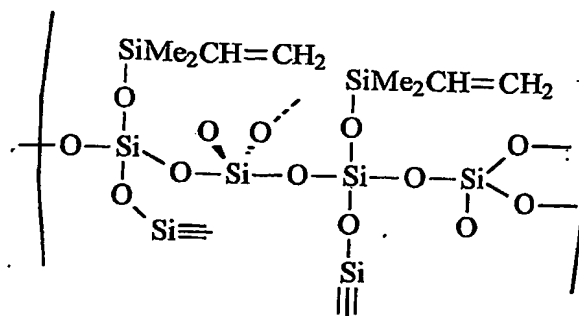
vinylsiloxane. The solder material may comprise any suitable solder material or metal, such as indium, silver, copper, aluminum, tin, bismuth, lead, gallium and alloys thereof, silver coated copper, and silver coated aluminum, but it is preferred that the solder material comprise indium or indium-based compounds.

5       The solder-based interface materials, as described herein, have several advantages directly related to use and component engineering, such as: a) the interface material/polymer solder material can be used to fill very small gaps on the order of 2 millimeters or smaller, b) the interface material/polymer solder material can efficiently dissipate heat in those very small gaps as well as larger gaps, unlike most conventional solder materials, and c) the interface  
10 material/polymer solder material can be easily incorporated into micro components, components used for satellites, and small electronic components.

Resin-containing interface materials and solder materials, especially those comprising silicone resins, that may also have appropriate thermal fillers can exhibit a thermal capability of less than  $0.5 \text{ cm}^2/\text{w}^\circ \text{C}$ . Unlike thermal grease, thermal performance of the material will not  
15 degrade after thermal cycling or flow cycling in IC devices because liquid silicone resins will cross link to form a soft gel upon heat activation.

Interface materials and polymer solders comprising resins, such as silicone resins, will not be "squeezed out" as thermal grease can be in use and will not display interfacial delamination during thermal cycling. The new material can be provided as a dispensable liquid  
20 paste to be applied by dispensing methods and then cured as desired. It can also be provided as a highly compliant, cured, and possibly cross-linkable elastomer film or sheet for pre-application on interface surfaces, such as heat sinks. Advantageously, fillers with a thermal conductivity of greater than about 2 and preferably at least about  $4 \text{ w/m}^\circ \text{C}$  will be used. Optimally, it is desired to have a filler of not less than about  $10 \text{ w/m}^\circ \text{C}$  thermal conductivity. The interface material  
25 enhances thermal dissipation of high power semiconductor devices. The paste may be formulated as a mixture of functional silicone resins and thermal fillers.

A vinyl Q resin is an activated cure specialty silicone rubber having the following base polymer structure:



Vinyl Q resins are also clear reinforcing additives for addition cure elastomers. Examples of vinyl Q resin dispersions that have at least 20% Q-resin are VQM-135 (DMS-V41 Base), VQM-146 (DMS-V46 Base), and VQX-221 (50% in xylene Base).

5 As an example, a contemplated silicone resin mixture could be formed as follows:

Component	% by weight	Note/Function
Vinyl silicone	75 (70-97 range)	Vinyl terminated siloxane
Vinyl Q Resin	20 (0-25 range)	Reinforcing additive
Hydride functional siloxane	5 (3-10 range)	Crosslinker
Platinum -vinylsiloxane	20-200 ppm	Catalyst

10 The resin mixture can be cured at either at room temperature or at elevated temperatures to form a compliant elastomer. The reaction is via hydrosilylation (addition cure) of vinyl functional siloxanes by hydride functional siloxanes in the presence of a catalyst, such as platinum complexes or nickel complexes. Preferred platinum catalysts are SIP6830.0, SIP6832.0, and platinum-vinylsiloxane.

15 Contemplated examples of vinyl silicone include vinyl terminated polydimethyl siloxanes that have a molecular weight of about 10000 to 50000. Contemplated examples of hydride functional siloxane include methylhydrosiloxane-dimethylsiloxane copolymers that have a molecular weight about 500 to 5000. Physical properties can be varied from a very soft gel material at a very low crosslink density to a tough elastomer network of higher crosslink density.



Solder materials that are dispersed in the resin mixture are contemplated to be any suitable solder material for the desired application. Preferred solder materials are indium tin (InSn) complexes, indium silver (InAg) complexes and alloys, indium-based compounds, tin silver copper complexes (SnAgCu), tin bismuth complexes and alloys (SnBi), and aluminum-based compounds and alloys. Especially preferred solder materials are those materials that comprise indium.

As with the previously described thermal interface materials and components, thermal filler particles may be dispersed in the resin mixture. If thermal filler particles are present in the resin mixture, then those filler particles should advantageously have a high thermal conductivity. Suitable filler materials include silver, copper, aluminum, and alloys thereof; boron nitride, aluminum spheres, aluminum nitride, silver coated copper, silver coated aluminum, carbon fibers, and carbon fibers coated with metals, metal alloys, conductive polymers or other composite materials. Combinations of boron nitride and silver or boron nitride and silver/copper also provide enhanced thermal conductivity. Boron nitride in amounts of at least 20 wt. %, aluminum spheres in amounts of at least 70 wt. %, and silver in amounts of at least about 60 wt. % are particularly useful. These materials may also comprise metal flakes or sintered metal flakes.

Of special efficacy is a filler comprising a particular form of carbon fiber referred to as "vapor grown carbon fiber" (VGCF) such as is available from Applied Sciences, Inc., Cedarville, Ohio. VGCF, or "carbon micro fibers", are a highly graphized type by heat treatment (thermal conductivity = 1900 w/m°C). Addition of about 0.5 wt. % carbon micro fibers provides significantly increased thermal conductivity. Such fibers are available in varying lengths and diameters; namely, 1 mm to tens of centimeters in length and from under 0.1 to over 100  $\mu\text{m}$  in diameter. One useful form has a diameter of not greater than about 1  $\mu\text{m}$  and a length of about 50 to 100  $\mu\text{m}$ , and possesses a thermal conductivity of about two or three times greater than with other common carbon fibers having diameters greater than 5  $\mu\text{m}$ .

It may also be advantageous to incorporate substantially spherical filler particles to maximize packing density. Additionally, substantially spherical shapes or the like will also

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provide some control of the thickness during compaction. Dispersion of filler particles can be facilitated by the addition of functional organo metallic coupling agents or wetting agents, such as organosilane, organotitanate, organozirconium, etc. The organo metallic coupling agents, especially organotitanate, may also be used to facilitate melting of the solder material during the application process. Typical particle sizes useful for fillers in the resin material may be in the range of about 1-20  $\mu\text{m}$  with a maximum of about 100  $\mu\text{m}$ .

To illustrate the invention, a number of examples were prepared by mixing the components described in Examples A through J below. The examples shown include one or more of the optional additions, e.g., wetability enhancer. The amounts of such additions may vary but, generally, they may be usefully present in the following approximate amounts (in wt. %): filler up to 95% of total (filler plus resins); wetability enhancer 0.1 to 5% (of total); and adhesion promoters 0.01 to 1% (of total). It should be noted the addition at least about 0.5% carbon fiber significantly increases thermal conductivity. The examples also show various physico-chemical measurements for the contemplated mixtures.

#### Polymer Solder/Interface Material Examples

Example	A	B	C	D	E	F	G	H	I	J
Silicone Mixture	16	5	8	5	5	5	5	5	4	4
Organotitanate	4	3	0	3	3	3	3	3	3	3
InSn		92	92	82						
InAg					63					
In						63				
SnAgCu							92	82		
SnBi										
Al	80			10	29	29			83	68
Modulus (MPa)	25	15	25	15	20	23	25	30	20	25
Viscosity (poises)	1400	500	1200	450	1500	1600	500	750	650	170
Thermal Impedence ( $\text{cm}^2\text{C/w}$ )	0.3	0.15	0.4	0.14	0.14	0.12	0.16	0.17	0.18	0.10
Thermal Conductivity	2.5	5.1	2.0	5.5	5.8	6.2	5.2	5.0	5.0	6.0

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(W/m°C)											
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Components organotitanate, InSn, InAg, In, SnAgCu, SnBi, and Al are presented as weight percent or as wt. %.

- Example A contains no solder material and is provided for reference purposes.
- 5 Organotitanate is functioning not only as a wetting enhancer, but also as a fluxing agent to facilitate melting of the solder material during the application process.

The solder compositions for these examples are as follows: InSn = 52% In (by weight) and 48% Sn (by weight) with a melting point of 118C; InAg = 97% In (by weight) and 3% Ag (by weight) with a melting point of 143C; In = 100% Indium (by weight) with a melting point of 157C; SnAgCu = 94.5% Tin (by weight), 3.5% Silver (by weight) and 2% Copper (by weight) with a melting point of 217C; SnBi = 60% Tin (by weight) and 40% Bismuth (by weight) with a melting point of 170C. It should be appreciated that other compositions comprising different component percentages can be derived from the subject matter contained herein.

- The processing temperatures are as follows: Examples A-E = 150C for 30 minutes;
- 15 Examples F, J and I = 200C for 30 seconds and 150C for 30 minutes; Examples G and H = 240C for 30 seconds and 150C for 30 minutes.

Another suitable interface material can also be produced/prepared that comprises a solder material. The solder material may comprise any suitable solder material or metal, such as indium, silver, copper, aluminum, tin, bismuth, lead, gallium and alloys thereof, silver coated copper, and silver coated aluminum, but it is preferred that the solder material comprise indium or indium-based compounds.

20

The solder-based interface materials, as described herein, have several advantages directly related to use and component engineering, such as: a) high bulk thermal conductivity, b) metallic bonds may be formed at the joining surfaces, lower contact resistance c) the interface solder material can be easily incorporated into micro components, components used for satellites, and small electronic components.

25

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An additional component, such as a low modulus metal coated polymer sphere or microspheres may be added to the solder material to decrease the bulk elastic modulus of the solder.

Heat spreader components or heat spreading components (heat spreader and heat spreading are used herein interchangeably and have the same common meaning) generally comprise a metal or metal-based base material, such as nickel, aluminum, copper, CuSiC, diamond, composite materials or AlSiC and/or other suitable materials that may not comprise metal. Any suitable metal or metal-based base material can be used herein as a heat spreader, as long as the metal or metal-based base material can dissipate some or all of the heat generated by the electronic component. Specific examples of contemplated heat spreader components are shown under the Examples section.

Heat spreader components can be laid down in any suitable thickness, depending on the needs of the electronic component, the vendor and as long as the heat spreader component is able to sufficiently perform the task of dissipating some or all of the heat generated from the surrounding electronic component. Contemplated thicknesses comprise thicknesses in the range of about 0.25 mm to about 6 mm. Especially preferred thicknesses of heat spreader components are within the range of about 1 mm to about 5 mm.

When using a metallic thermal interface material, like solder, which has a high elastic modulus compared to most polymer systems, it may be necessary to reduce coefficient of thermal expansion mismatch generated mechanical stresses transferred to the semiconductor die in order to prevent cracking of the die. This stress transfer can be minimized by increasing the bondline of the metallic thermal interface material, reducing the coefficient of thermal expansion of the heat spreader, or change the geometry of the heat spreader to minimize stress transfer. Examples of lower Coefficient of thermal expansion materials are AlSiC, CuSiC, Copper-graphite composites, Carbon-Carbon composites, Diamonds, CuMoCu laminates, etc. Examples of geometric changes are adding a partial or through slot to the spreader to decrease spreader thickness and forming a truncated, square based, inverted pyramid shape to lower stress and stiffness by having the spreader crosssection be lower near the semiconductor die.

A method of forming contemplated layered interface materials comprises: a) providing a crosslinkable thermal interface component; b) providing a heat spreader component; and c) physically coupling the thermal interface component and the heat spreader component.

5 The crosslinkable thermal interface components and the heat spreader components can be individually prepared and provided by using the methods previously described herein. The two components are then physically coupled to produce a layered interface material. As used herein, the term "interface" means a couple or bond that forms the common boundary between two parts of matter or space. An interface may comprise a physical attachment or physical couple of two parts of matter or components or a physical attraction between two parts of matter or components, including bond forces such as covalent and ionic bonding, and non-bond forces such as Van der Waals, electrostatic, coulombic, hydrogen bonding and/or magnetic attraction. 10 The two components, as described herein, may also be physically coupled by the act of applying one component to the surface of the other component.

The layered interface material may then be applied to a substrate, another surface, or 15 another layered material. The electronic component comprises a layered interface material, a substrate layer and an additional layer. The layered interface material comprises a heat spreader component and a thermal interface component. Substrates contemplated herein may comprise any desirable substantially solid material. Particularly desirable substrate layers would comprise films, glass, ceramic, plastic, metal or coated metal, or composite material. In preferred 20 embodiments, the substrate comprises a silicon or germanium arsenide die or wafer surface, a packaging surface such as found in a copper, silver, nickel or gold plated leadframe, a copper surface such as found in a circuit board or package interconnect trace, a via-wall or stiffener interface ("copper" includes considerations of bare copper and its oxides), a polymer-based packaging or board interface such as found in a polyimide-based flex package, lead or other 25 metal alloy solder ball surface, glass and polymers such as polymimide. The "substrate" may even be defined as another polymer material when considering cohesive interfaces. In more preferred embodiments, the substrate comprises a material common in the packaging and circuit board industries such as silicon, copper, glass, and another polymer.

Additional layers of material may be coupled to the layered interface materials in order to continue building a layered component or printed circuit board. It is contemplated that the additional layers will comprise materials similar to those already described herein, including metals, metal alloys, composite materials, polymers, monomers, organic compounds, inorganic compounds, organometallic compounds, resins, adhesives and optical wave-guide materials.

A layer of laminating material or cladding material can be coupled to the layered interface materials depending on the specifications required by the component. Laminates are generally considered fiber-reinforced resin dielectric materials. Cladding materials are a subset of laminates that are produced when metals and other materials, such as copper, are incorporated into the laminates. (Harper, Charles A., *Electronic Packaging and Interconnection Handbook*, Second Edition, McGraw-Hill (New York), 1997.)

Spin-on layers and materials may also be added to the layered interface materials or subsequent layers. Spin-on stacked films are taught by Michael E. Thomas, "Spin-On Stacked Films for Low  $k_{eff}$  Dielectrics", *Solid State Technology* (July 2001), incorporated herein in its entirety by reference.

Applications of the contemplated thermal solutions, IC Packages, thermal interface components, layered interface materials and heat spreader components described herein comprise incorporating the materials and/or components into another layered material, an electronic component or a finished electronic product. Electronic components, as contemplated herein, are generally thought to comprise any layered component that can be utilized in an electronic-based product. Contemplated electronic components comprise circuit boards, chip packaging, separator sheets, dielectric components of circuit boards, printed-wiring boards, and other components of circuit boards, such as capacitors, inductors, and resistors.

Electronic-based products can be "finished" in the sense that they are ready to be used in industry or by other consumers. Examples of finished consumer products are a television, a computer, a cell phone, a pager, a palm-type organizer, a portable radio, a car stereo, and a remote control. Also contemplated are "intermediate" products such as circuit boards, chip packaging, and keyboards that are potentially utilized in finished products.



Isopropyl alcohol

MATERIAL

Heat Spreader Component per Honeywell specifications

Pre-cut PCM material per Honeywell specifications or suitable phase change material per specifications of the vendor and/or manufacturer.

Fixturing (specific fixturing, preferably nylon, for the component and PCM material)

SAFETY AND ENVIRONMENT

Safety glasses

When operating any type of conveyor, always make sure hands are clear of any pinch

INSTRUCTIONS

Pull a 32 piece random sample of the component for outgoing inspection prior to applying PCM material. See following discussion of Nickel Plated Heat Spreader Quality Requirements and Criteria for typical visual inspection criteria.

Use only a phase change material that has passed the inspection criteria similar to those discussed herein; Start with Room temp. phase change material, such as PCM 45. If the both top and bottom release liners fall off prematurely, warm the PCM material for >0.5 hr at 30C

Ensure that the substrate temperature is greater than 21C

Apply the phase change material to component per the following instructions:

The release liner is (short one preferably) removed to expose the phase change material to apply the material to the component as per Figure 2



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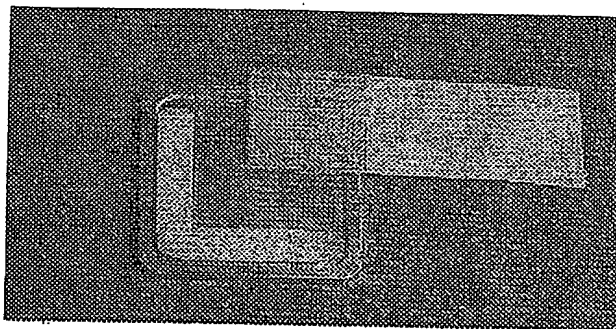


Figure 2

5

Locate the alignment jig on the component, apply the phase change material with light finger pressure as per Figures 3 and 4

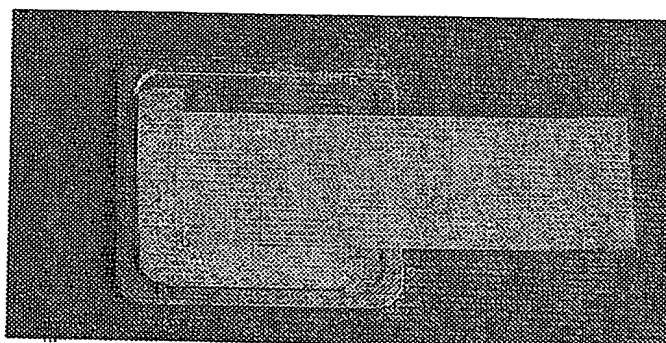


Figure 3

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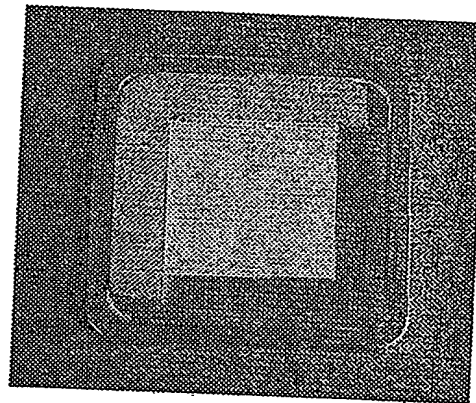


Figure 4

5

Run through heat tunnel (Figures 5 and 6) to bring the combination part to an exit temperature of between 48 and 60C. Residence time can be from 30 to 60 seconds.

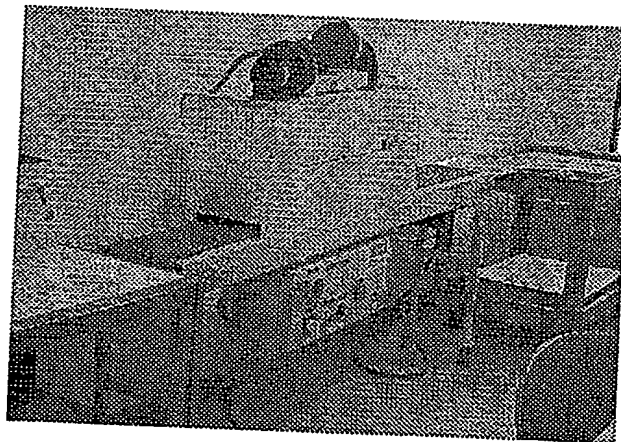


Figure 5

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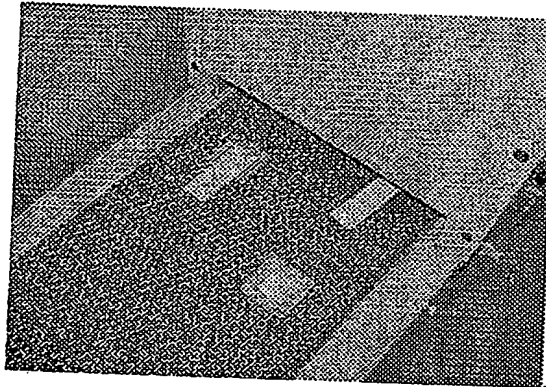


Figure 6

5 Apply light finger pressure to PCM 45 to ensure complete attachment

Refrigerate to less than  $-10^{\circ}\text{C}$  for greater than ten minutes

Remove top liner

10 Visually inspect combination part for defects

Load into trays

15  
QUALITY REQUIREMENTS

20 Sampling Plan.

25 Inspect each component after application for location and visual requirements.

Inspection Instructions.

30 At 1X, 12"-14" from the eye, visually inspect the PCM material to insure location and visual criteria.

Accept/Reject Criteria.

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Visually inspect for any deformation around the edges of the material. See Figures 7-9 for visual examples. Also re-inspect the substrate for staining and or scratches as per the relevant quality workmanship standards for the component.

5

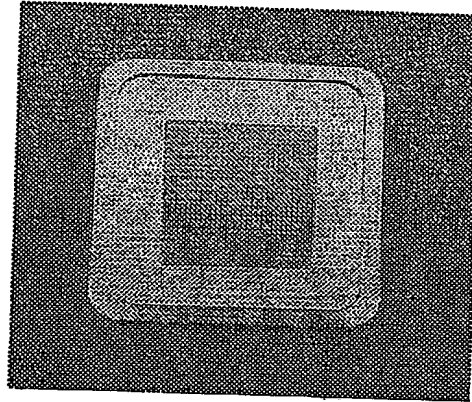


Figure 7 – Perfect Attachment -Pass

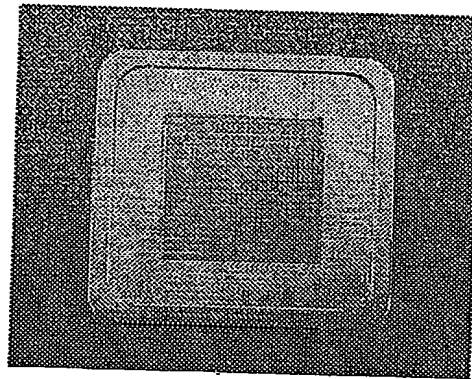


Figure 8 Good Attachment – top edge of phase change material not  
parallel with substrate-pass

10

15

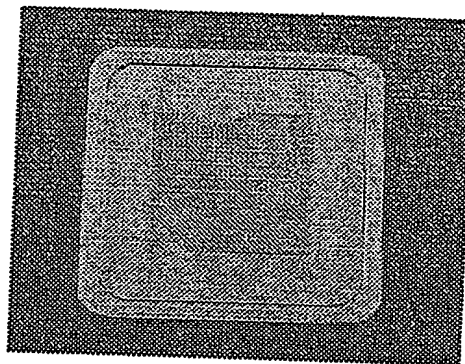


Figure 9 - phase change material torn -did not separate from liner-fail

Note: If this failure occurs, the parts need to be left the refrigerator longer

Visually inspect for locations per product specifications. See the Control Plan for the location specifications. Rework shall be completed at time of inspection.

Rework of phase change material component application

Phase change material component failing visual inspection can be reworked immediately.

Using a Plastic scraper, remove the rejected phase change material from the component.

Use isopropyl alcohol and a wipe to remove any adhesive.

Return to second step under Instructions where phase change material component is provided.

Disposition Instructions.

Acceptable Material.

Acceptable material will be processed per standard operating instructions. No special tag will be attached to conforming material.

Non-Conforming Material.

5 Rejected material will be marked with a red rejection tag and isolated from accepted material. The rejection tag is to be used for identifying and routing rejected material for disposal and should be completely filled out.

10 Questionable material awaiting disposition will be marked with a yellow hold tag and isolated from accepted material. The hold tag is to be used for identifying and isolating material and should be completely filled out. Any employee can place material "Hold". All material that is placed on "Hold" can not leave that operation until an MRB is held and the material status has been determined.

15 Quarantined Material is material that can be processed through the manufacturing process but not shipped. Examples are non-conforming material that has been approved by the customer for use, material needing inspection or parts that were produced on equipment that has not been certified. The orange quarantine tag is used to identify the material, control the material (prevent shipping of the material) and has to be filled out completely.

20 The root cause, and the preventive action, of non-conforming material may be identified through the use of a Corrective Action Request.

Honeywell Docket No.: Not Assigned (4015)  
 Riordan Docket No.: 54-009-001

03453715 03453715

Dimensional and Heat Spreader Component (Nickel) Thickness Standards

Sample Sizes: 1 out of every 1,500 pieces (Dimensional and X-Ray Fluorescence (XRF) measurements) CMM = Coordinate Measurement Machine

5

0.10 AQL, C=0 (Visual)

**Table 1: Dimensional and Nickel Thickness Requirements**

Parameter	Metrology	Criteria/Disposition	Cpk
Outside Length/Width	CMM (touch or optical)	$37.5 \pm 0.05$ mm	1.33
Flange Width	CMM (touch or optical)	$2.5 \pm 0.15$ mm	1.33
Cavity Depth	CMM (touch or optical)	$0.60 \pm 0.025$ mm	1.33
Overall Thickness	Micrometer	$3.0 \pm 0.1$ mm	1.33
Flatness (Topside)	<ul style="list-style-type: none"> <li>CMM (optical or touch)</li> <li>.035mm max 2mm from edge</li> </ul>	9 point array	1.33
Flatness (Cavity)	<ul style="list-style-type: none"> <li>CMM (optical or touch)</li> <li>.025mm max in 22mm sq. area in center.</li> </ul>	9 point array	1.33
Nickel Thickness @ Center of Top Side	XRF	3 to 10 $\mu$ m	1.33
Flange Surface Roughness	Profilometer, 2.5cm stroke	Less than 1 $\mu$ m	NA
PCM45 Attached Thickness	Linear Measurement Tools	$0.25$ mm $\pm$ 0.06mm	NA
PCM45 Attached Length/Width	Linear Measurement Tools	$20$ mm $\pm$ 2.0 mm	1.33
PCM45 Location	Mask	Located within center 23mm area of cavity	NA

Honeywell Docket No.: Not Assigned (4015)  
 Riordan Docket No.: 54-009-001

PCM45 Thermal Impedance (Measured on bulk sample)	ASTM D5470	$\leq 0.35 \text{ Ccm}^2/\text{W}$ at 30 psi and $0.001'' \leq \text{BLT} \leq 0.002''$	1.33
PCM45 Phase Change (peak Temperature, Measured on bulk material)	DSC (@N <sub>2</sub> , 5°C/min)	45 °C +/- 8 °C	1.33

## 1. Visual Standards

- 5 Visual inspection performed at 1X on both sides of part at a distance of 12" to 24" with direct overhead white fluorescent lighting. Heat spreader angle can be altered to find stains that may be invisible due to light reflection (birefringence).

Defect	Metrology	Criteria
<b>Dents:</b> Depression of material, typically by mechanical force.	Visual	<ul style="list-style-type: none"> <li>Reject part if greater than 2 mm in any direction and has a depth of greater than 0.05 mm.</li> </ul>
<b>Scratches:</b> A surface imperfection due to abrasion that removes a channel of material.	Visual	<ul style="list-style-type: none"> <li>Reject part if larger than 3 mm in any direction and depth can be determined by finger touch wearing gloves.</li> <li>Reject if there is excessive light scratching over the entire surface of the part.</li> <li>Oriented rolling marks in raw material are not considered to be scratches.</li> </ul>
<b>Foreign Material/Contamination:</b> Material or residue adhering to or embedded in the surface.	Visual	<ul style="list-style-type: none"> <li>Reject part if greater than 0.5 mm on Nickel surface in any direction or can not be removed with 30 psi of air.</li> <li>Reject part if foreign material within PCM45 is detectable by unaided eye.</li> </ul>



Honeywell Docket No.: Not Assigned (4015)  
 Riordan Docket No.: 54-009-001

Defect	Metrology	Criteria
<b>Stain/Discoloration:</b> Change in color of surface with a definite border.	Visual	<ul style="list-style-type: none"> <li>Visual ruler to be developed based on feedback from vendor on functional requirements.</li> <li>Reject if area on PCM45 surface is greater than 7 mm in any direction.</li> </ul>
<b>Exposed Copper/Voids:</b> Exposed base metal that is not covered by plating.	Visual	<ul style="list-style-type: none"> <li>None allowed on top side or cavity side.</li> <li>Exposed copper allowed on edges due to rack contact. Exposed copper is not to exceed 1 mm per rack contact location.</li> </ul>
<b>Burr:</b> Excess material along the sharp edge of part.	Visual – Verify by micrometer	<ul style="list-style-type: none"> <li>Edges: reject if greater than 0.05 mm protrusion.</li> </ul>
<b>Bump:</b> Excess material on flat surfaces, not present by design.	Visual – Verify by micrometer	<ul style="list-style-type: none"> <li>Reject part if greater than 0.05 mm in height.</li> </ul>
<b>Peeling/Delamination:</b> Separation of plating material from surface.	Visual	<ul style="list-style-type: none"> <li>None allowed</li> </ul>
<b>Blister:</b> Bubble or smooth mound of plating that has separated from the underlying surface.	10 pieces per lot will be baked at 300 C for 10 minutes and visually inspected at 10X.	<ul style="list-style-type: none"> <li>No more than 3 or one blister greater than 0.2 mm</li> </ul>
<b>Brightness</b>	X-Rite Model 404 densitometer with 3.4mm aperture	<ul style="list-style-type: none"> <li>0.45-1.25 with final limits based upon vendor feedback</li> </ul>

Honeywell Docket No.: Not Assigned (4015)  
 Riordan Docket No.: 54-009-001

Defect	Metrology	Criteria
	Visual	<ul style="list-style-type: none"> <li>Reject if any voids or tears are present in interior 15 mm x 15 mm area of the PCM pad.</li> <li>Reject if missing material greater than 0.5 mm (any dimension) along the pad perimeter area (outside 15 x 15 mm central area) and void or tear extends through the thickness of the phase change material (PCM) pad.</li> <li>None allowed.</li> </ul>
PCM Lifting: Non-adhesion or detachment of the PCM45 material from Nickel plated copper surface.	Visual	<ul style="list-style-type: none"> <li>Reject if non-adhered area extends more than 1 mm from any edge.</li> </ul>

## 2. Packaging Standards

Parameter	Description
Tray	<ul style="list-style-type: none"> <li>Trays are per customer/vendor specification</li> <li>Parts to be loaded cavity down</li> </ul>
PCM45	Exposed – no tab
Stack Height	4 full trays with one empty cover tray
Labels	<ul style="list-style-type: none"> <li>Label requirements for cover tray               <ul style="list-style-type: none"> <li>Date</li> <li>Quantity</li> <li>Part Size</li> <li>Lot Number</li> <li>Part Number</li> <li>Description</li> <li>Purchase Order Number</li> <li>MSDS</li> </ul> </li> <li>Label on bottom of trays               <ul style="list-style-type: none"> <li>Label to be placed on the outside of bag.</li> <li>Label to state "Turn over before opening"</li> </ul> </li> </ul>
Straps	Each stack will be strapped 4 times (2 straps in one direction, rotate stack and strap twice again)
Bags	Each stack will be place in bag, open end will be heat-sealed and the air from the bag will be removed using a vacuum.
Box	<ul style="list-style-type: none"> <li>Place stacks of parts such that the "Turn over before opening" is at the top of the box.</li> <li>Box to be labeled with a label containing all the information on the cover tray. The quantity should reflect the total quantity in the box.</li> <li>The box is not to contain more than 300 pieces (maximum 3 stacks per box).</li> <li>Each box is to be marked X of XX per lot. X is the box number and the XX is the total number of boxes for the lot.</li> </ul>

## 5 3. Storage Condition and Shelf Life

Final Parts shall be kept in sealed bag at about room temperature ( $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$ ). Avoid excess heat (more than  $40^{\circ}\text{C}$ ) and direct sun exposure or extreme cold (less than  $5^{\circ}\text{C}$ ). Do not apply more than about 5 psi pressure to exposure phase change material (PCM) surface. Shelf life is about 1 year from product manufacture.

As discussed herein, the thermal interconnect system, thermal interface and interface materials are beneficial for many reasons. One reason is that the heat spreader component and

interface material has excellent wetting at the interface between the heat spreader component and the interface material, and this interfacial wetting is able to withstand the most extreme conditions. A second reason is that the heat spreader component/ thermal interface material combination disclosed and discussed herein reduces the number of steps necessary for package assembly by the customer - given that its pre-assembled and quality checked before the customer receives it. The pre-assembly of the component also reduces the associated costs on the part of the customer. A third reason is that the heat spreader component and the thermal interface material can be designed to "work together", so that the interfacial thermal resistance is minimized for the specific combination of heat spreader component and thermal interface material.

### Example 2

As mentioned earlier, pre-attached/pre-assembled thermal solutions and/or IC (interconnect) packages comprise one or more components of the thermal interface materials described herein and at least one adhesive component. A contemplated pre-attached/pre-assembled thermal solution is shown in Figure 1. Data showing the incorporation of some of the contemplated adhesive components are shown in Figures 10 and 11 and Tables 2 and 3. The adhesive component described in these Figures was cut to 10 mm by 10 mm and placed between the substrate/surface and the heat spreader. The adhesion strength of the tape was measured before and after preconditioning.

Figure 12 shows another contemplated pre-attached/pre-assembled thermal solution. For this thermal solution, SONY T4100 D203 was used as the at least one adhesive component. The adhesion strength of the adhesive component was evaluated after preconditioning. The tape was cut to cover the outer ring of the heat spreader. It was observed that the thickness of the double-sided tape was too thin. Clips were used to hold the samples together and to prevent separation of the substrate and heat spreader. Figure 13 and Table 4 show the data collected from this contemplated embodiment.

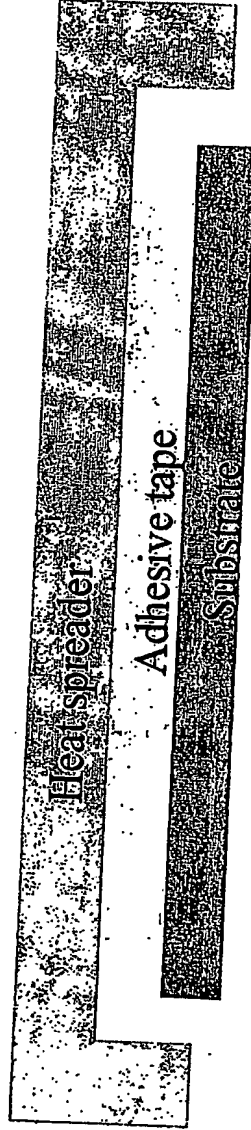
Figure 14 shows yet another contemplated embodiment of the pre-attached/pre-assembled thermal solution. For this thermal solution, two types of adhesive components were

evaluated and used: 3M F9460PC and SONY T4100 D203. Each of the adhesive components was cut to cover the outer ring of the heat spreader. The adhesion strength of each of the adhesive components was measured before and after preconditioning. Figures 15 and 16 and Tables 5 and 6 show the data collected from these contemplated embodiments.

5 Thus, specific embodiments and applications of thermal solutions, IC packaging, thermal interconnect and interface materials have been disclosed. It should be apparent, however, to those skilled in the art that many more modifications besides those already described are possible without departing from the inventive concepts herein. The inventive subject matter, therefore, is not to be restricted except in the spirit of the disclosure. Moreover, in interpreting the disclosure,  
10 all terms should be interpreted in the broadest possible manner consistent with the context. In particular, the terms "comprises" and "comprising" should be interpreted as referring to elements, components, or steps in a non-exclusive manner, indicating that the referenced elements, components, or steps may be present, or utilized, or combined with other elements, components, or steps that are not expressly referenced.

15

# Package outline 1

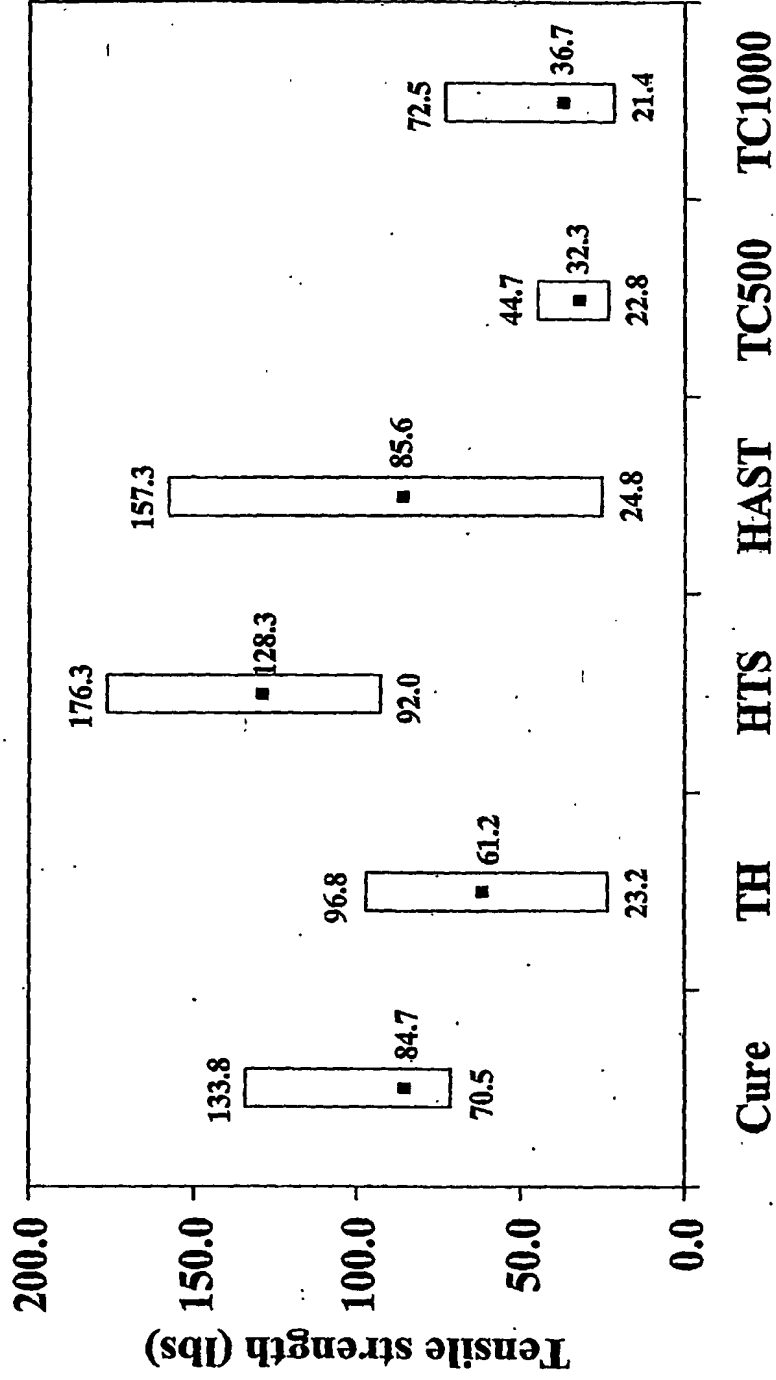


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# SONY T4100 D203

## Results



# SONY T4100 D203

## Results

Sample #	After cure		After temperature humidity (85C/85%RH for 168 hrs)		After high temperature storage 125C for 500 hours		After HAST 130C/ 85% RH for 96 hours		After temperature cycling 500 cycles		After temperature cycling 1000 cycles	
1	89.75	cohesive failure	98.75	cohesive failure	176.30	EF	77.05	cohesive failure	27.35	cohesive failure	49.20	cohesive failure
2	88.37	cohesive failure	58.30	cohesive failure	120.20	EF	79.40	cohesive failure	28.90	cohesive failure	21.35	cohesive failure
3	73.62	cohesive failure	74.55	cohesive failure	130.30	cohesive failure	98.25	cohesive failure	41.35	cohesive failure	37.25	cohesive failure
4	78.55	cohesive failure	25.25	cohesive failure	117.70	cohesive failure	102.30	cohesive failure	44.70	cohesive failure	27.85	cohesive failure
5	78.02	cohesive failure	23.15	EF	114.20	cohesive failure	98.75	cohesive failure	42.90	cohesive failure	49.15	cohesive failure
6	72.20	cohesive failure	65.20	cohesive failure	148.40	EF	24.75	cohesive failure	36.35	cohesive failure	35.75	cohesive failure
7	88.75	cohesive failure	69.55	cohesive failure	98.70	EF	157.30	cohesive failure	23.35	cohesive failure	42.35	cohesive failure
8	70.45	cohesive failure	77.70	cohesive failure	92.00	cohesive failure	75.25	cohesive failure	22.80	cohesive failure	22.75	cohesive failure
9	73.45	cohesive failure	41.35	cohesive failure	135.70	cohesive failure	68.95	cohesive failure	25.80	cohesive failure	38.70	cohesive failure
10	133.80	cohesive failure	80.45	EF	149.00	cohesive failure	74.10	cohesive failure	28.80	cohesive failure	72.50	cohesive failure
Max	133.80			96.75	176.30		157.30		44.70		72.50	
Avg	84.70			61.23	128.25		85.61		32.33		39.69	
Min	70.45			23.15	92.00		24.75		22.80		21.35	

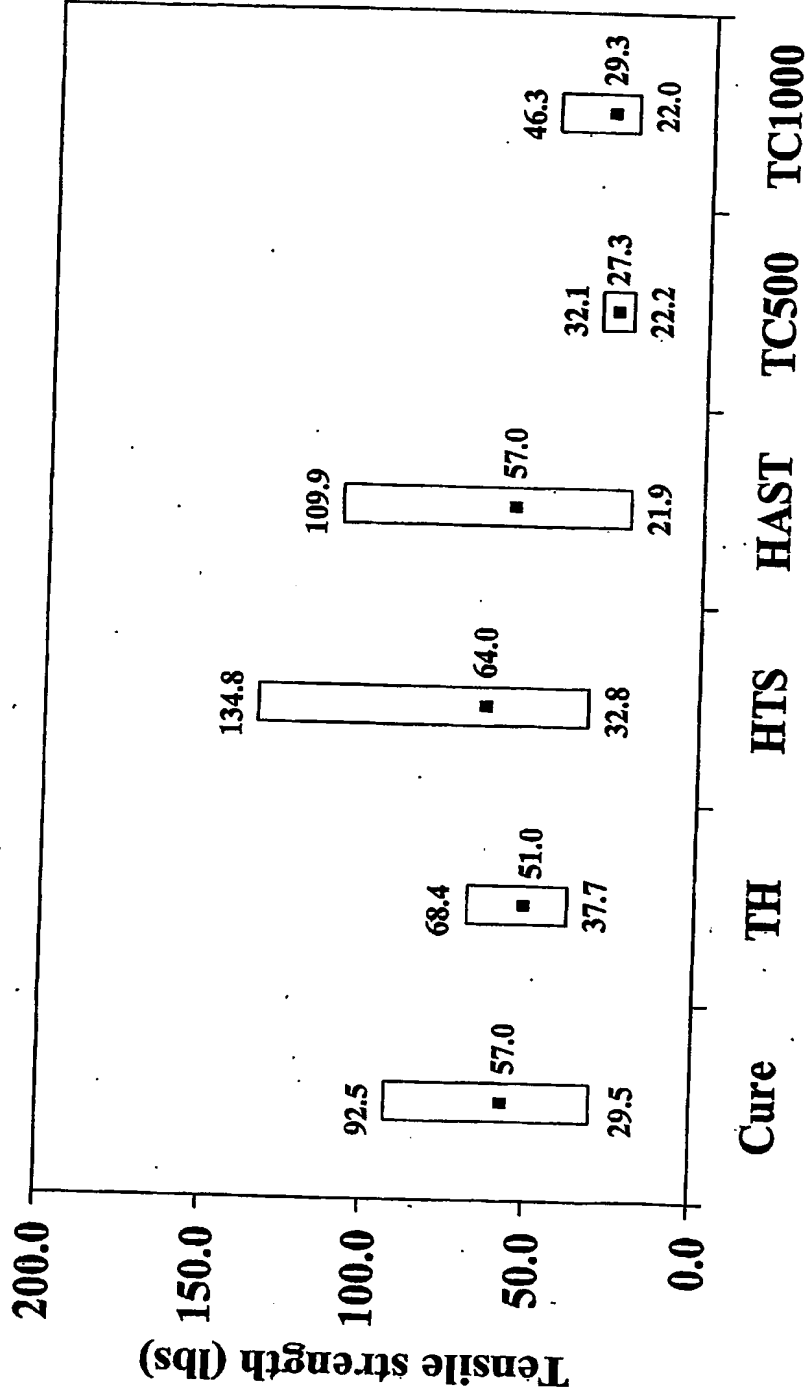
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Table 2



# SONY T4411

## Results



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# SONY T4411

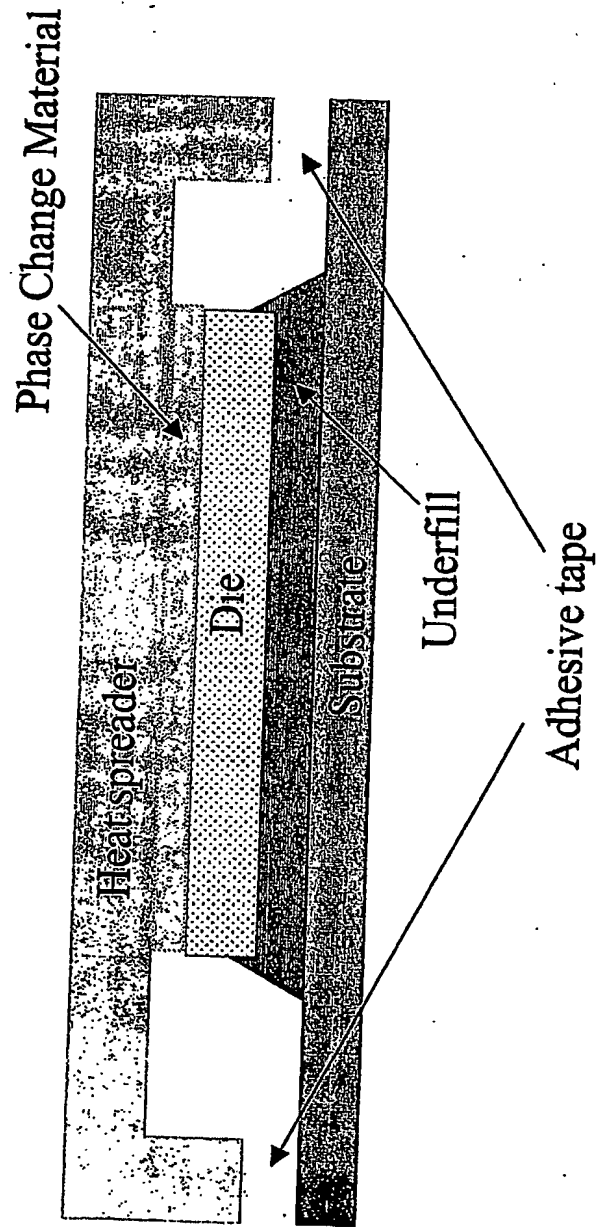
## Results

Sample#	After cure		After HAST 130C/ 85% RH for 96 hours		After temperature humidity (85C/85%RH for 168 hrs)		After high temperature storage 125C for 500 hours		After temperature cycling 500 cycles		After temperature cycling 1000 cycles	
	73.35	After cure	21.90	cohesive failure	42.20	cohesive failure	55.40	cohesive failure	32.10	cohesive failure	26.70	cohesive failure
1	73.35	cohesive failure	21.90	cohesive failure	42.20	cohesive failure	55.40	cohesive failure	32.10	cohesive failure	26.70	cohesive failure
2	29.45	cohesive failure	58.30	cohesive failure	55.05	cohesive failure	94.50	cohesive failure	29.65	cohesive failure	24.50	cohesive failure
3	37.40	cohesive failure	52.15	cohesive failure	37.65	cohesive failure	32.80	cohesive failure	27.20	cohesive failure	46.25	cohesive failure
4	50.20	cohesive failure	28.55	cohesive failure	38.40	cohesive failure	45.05	cohesive failure	25.80	cohesive failure	31.75	cohesive failure
5	59.95	cohesive failure	109.90	cohesive failure	45.05	cohesive failure	52.75	cohesive failure	26.30	cohesive failure	29.10	cohesive failure
6	45.85	cohesive failure	45.30	cohesive failure	68.40	cohesive failure	42.55	cohesive failure	24.65	cohesive failure	21.95	cohesive failure
7	56.85	cohesive failure	86.85	cohesive failure	53.70	cohesive failure	44.65	cohesive failure	29.60	cohesive failure	28.80	cohesive failure
8	72.80	cohesive failure	58.65	cohesive failure	52.65	cohesive failure	38.50	cohesive failure	22.15	cohesive failure	35.35	cohesive failure
9	51.80	cohesive failure	40.70	cohesive failure	62.10	cohesive failure	134.80	cohesive failure	28.10	cohesive failure	25.60	cohesive failure
10	92.45	cohesive failure	67.50	cohesive failure	55.20	cohesive failure	98.95	cohesive failure	27.00	cohesive failure	25.25	cohesive failure
Max	92.45		109.90		68.40		134.80		32.10		46.25	
Avg	57.01		56.98		51.04		64.00		27.27		29.33	
Min	29.45		21.90		37.65		32.80		22.15		21.85	

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Table 03

# Package outline 2

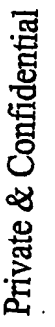


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Figure 2

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## Results

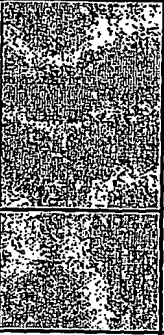
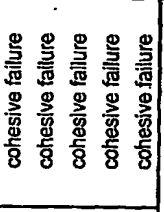


Frage 10

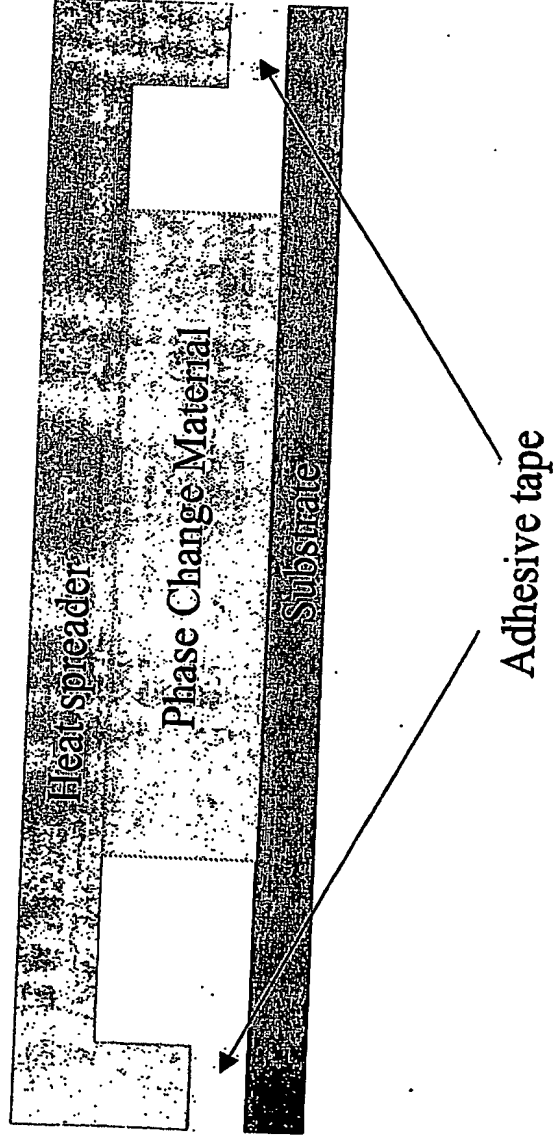
**SECRET**

# SONY T4100 D203

## Results

Sample #	After HAST 130C/ 85% RH for 96 hours		After temperature humidity (85C/85%RH for 168 hrs)		After temperature cycling 1st 500 cycles	
1	22.75	cohesive failure	22.80	cohesive failure	33.40	cohesive failure
2	25.30	cohesive failure	33.20	cohesive failure	73.27	cohesive failure
3	30.30	cohesive failure	20.90	cohesive failure	81.92	cohesive failure
4	20.20	cohesive failure	20.75	cohesive failure	57.57	cohesive failure
5	42.30	cohesive failure	32.95	cohesive failure	25.00	cohesive failure
6	28.55	cohesive failure	26.35	cohesive failure		
7	23.75	cohesive failure	18.35	cohesive failure		
8	14.35	cohesive failure	29.40	cohesive failure		
9	21.20	cohesive failure	26.30	cohesive failure		
10	36.65	cohesive failure	25.10	cohesive failure		
Max	42.30		33.20		81.92	
Avg	26.54		25.61		54.23	
Min	14.35		18.35		25.00	

# Package outline 3



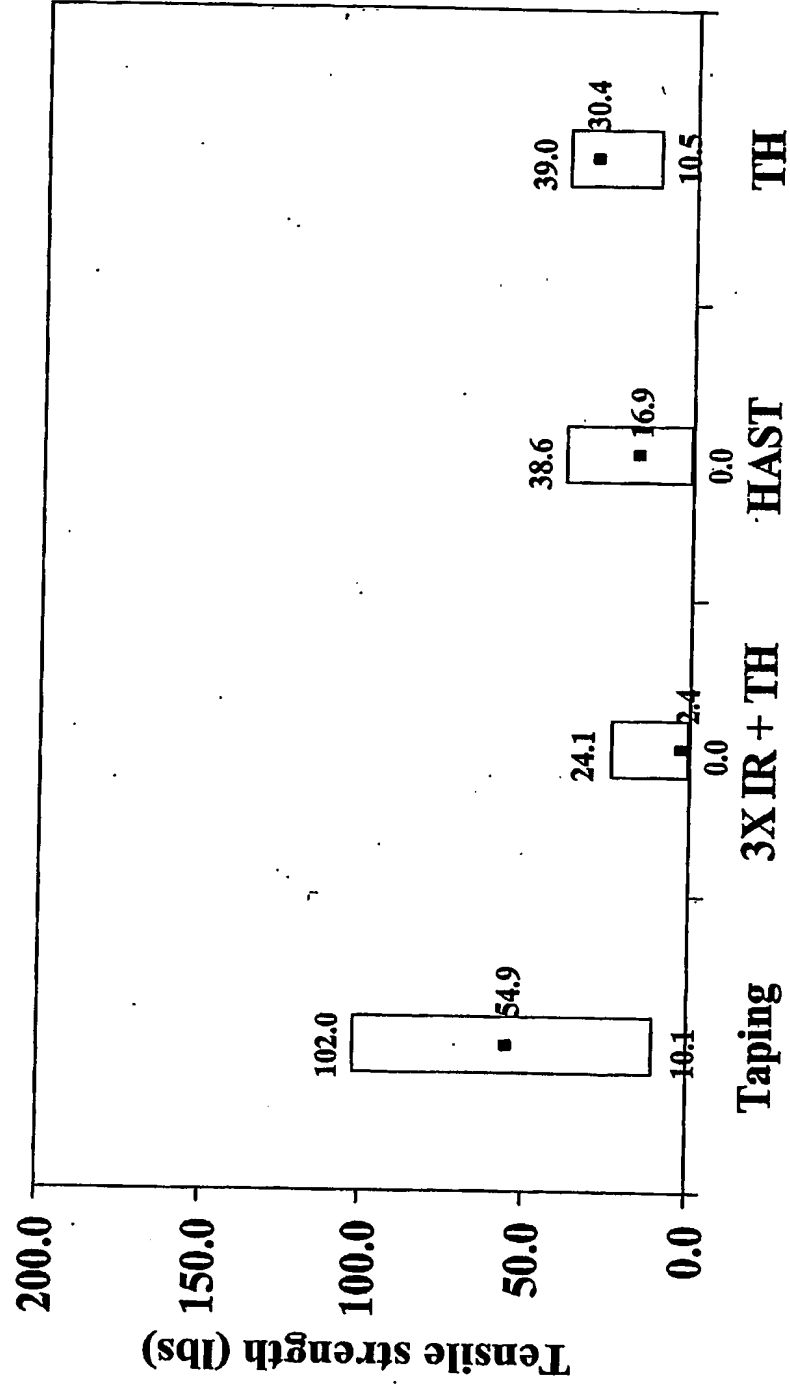
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Final 14

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# 3M F9460PC

## Results



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Final

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# 3M F9460PC

## Results

Sample #	After taping	3X IR reflow + 85C/85%RH 96hrs	After HAST 130C/ 85% RH for 96 hours	After temp humidity (85C/85%RH for 168 hrs)
1	57.0	24.1	0.0	39.0
2	102.0	0.0	29.7	32.9
3	67.6	0.0	10.0	36.7
4	78.7	0.0	21.5	33.8
5	11.4	0.0	10.5	36.3
6	10.2	0.0	10.8	36.5
7	59.2	0.0	11.9	10.5
8	10.1	0.0	38.6	22.9
9	54.3	0.0	25.4	27.4
10	98.8	0.0	10.9	27.7
Max	102.0	24.1	38.6	39.0
Avg	54.9	2.4	16.9	30.4
Min	10.1	0.0	0.0	10.5

\*\* The results for 500 cycles expected to be completed by last week of December

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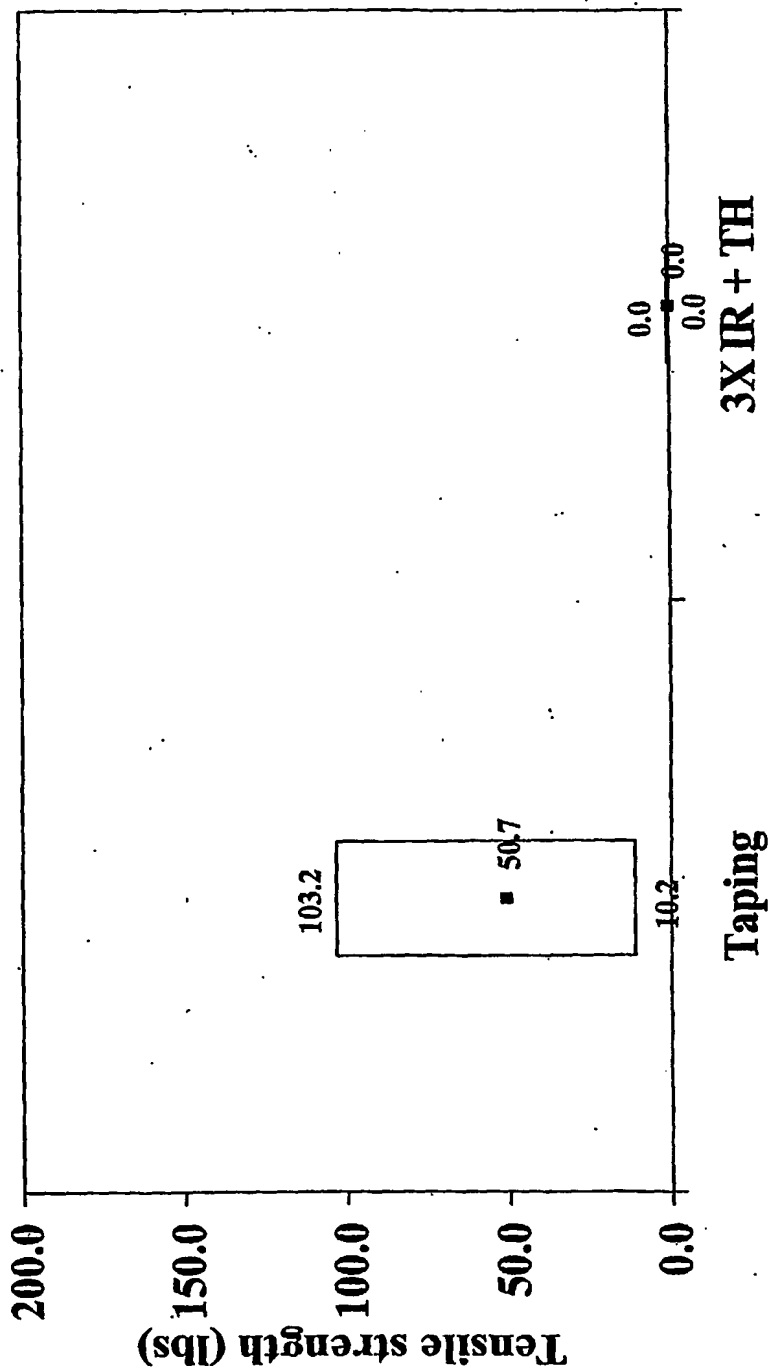
Table 5

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# SONY T4100 D203

## Results



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Figure 16

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# SONY T4100 D203

## Results

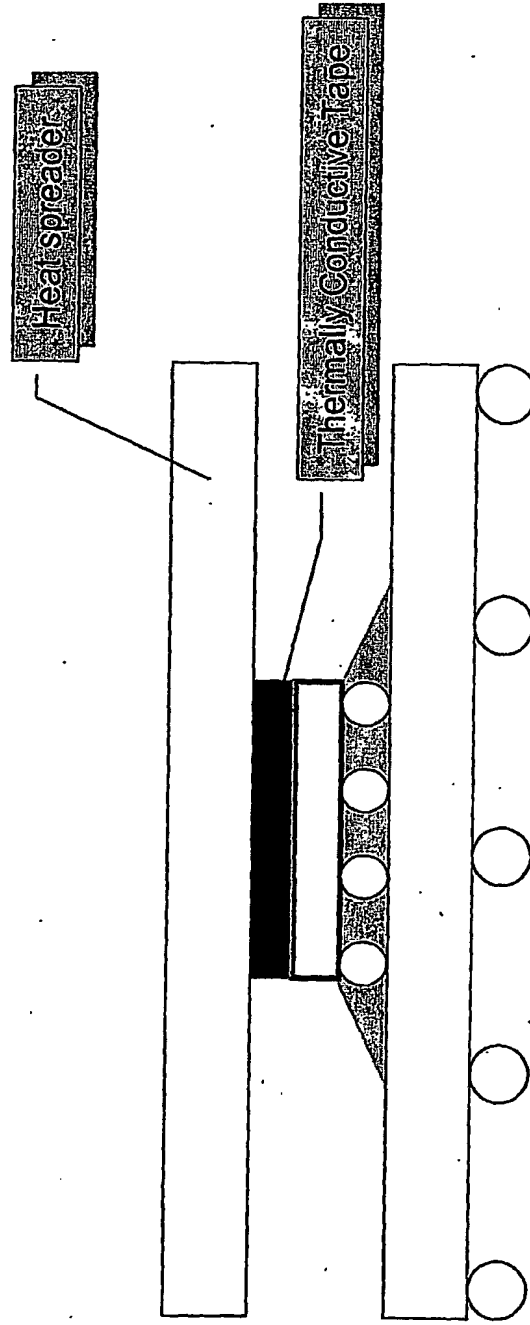
Sample #	After taping	3X Reflow + TH
1	103.2	0.0
2	81.1	0.0
3	34.6	0.0
4	61.3	0.0
5	13.2	0.0
6	13.0	0.0
7	13.0	0.0
8	10.2	0.0
9	102.3	0.0
10	75.8	0.0
Max	103.2	0.0
Avg	50.7	0.0
Min	10.2	0.0

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Table 6

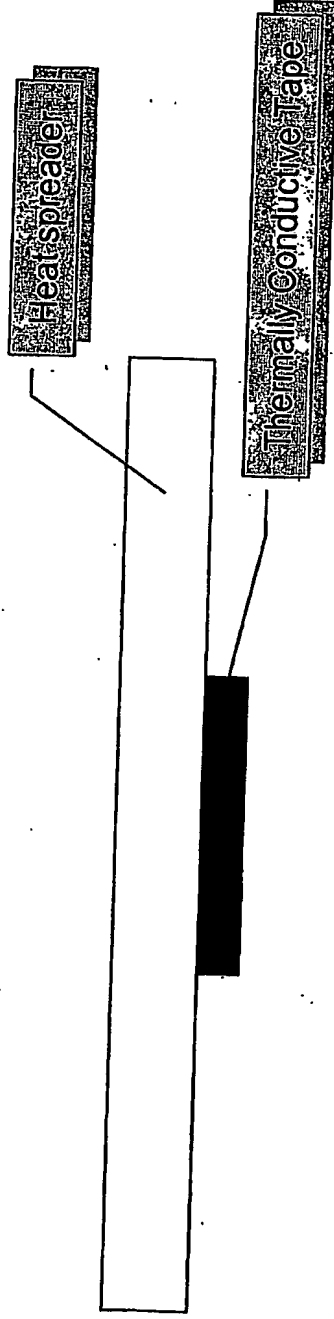
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# IC Package with Combospreader Type 1



Line 17

# Combospreader Type 1



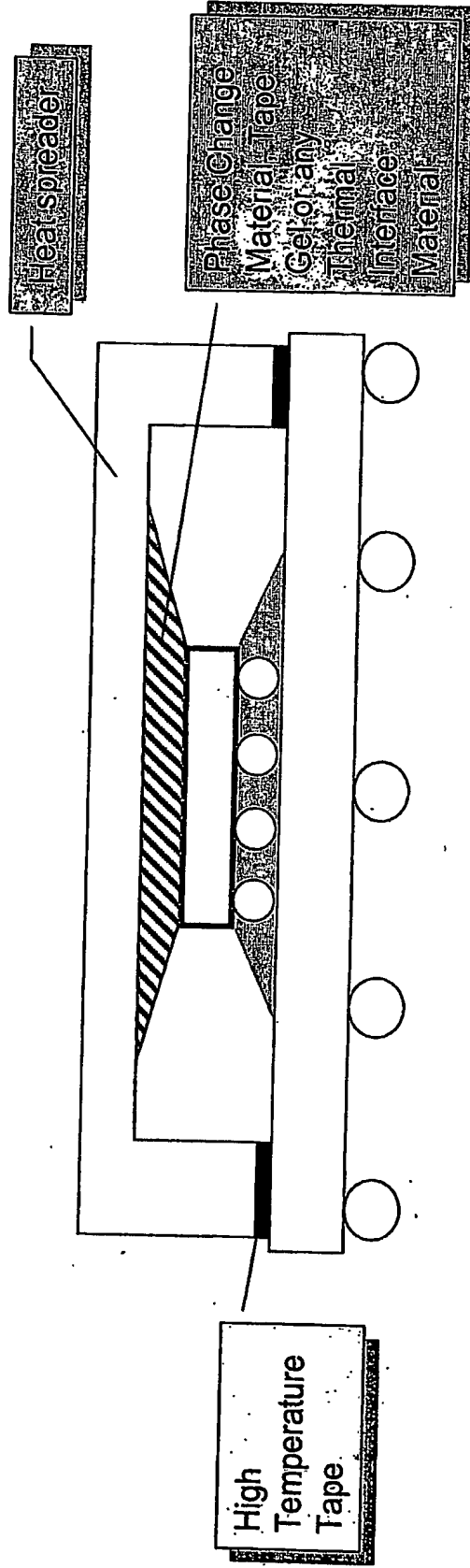
## Heat Spreader

- Material may be Copper, Aluminium, alloy (e.g. Alloy 42) or a composite (e.g. AlSiC)
- Shape design may be stamped, machined, coined or etched

## Thermally Conductive Tape

Figure 18

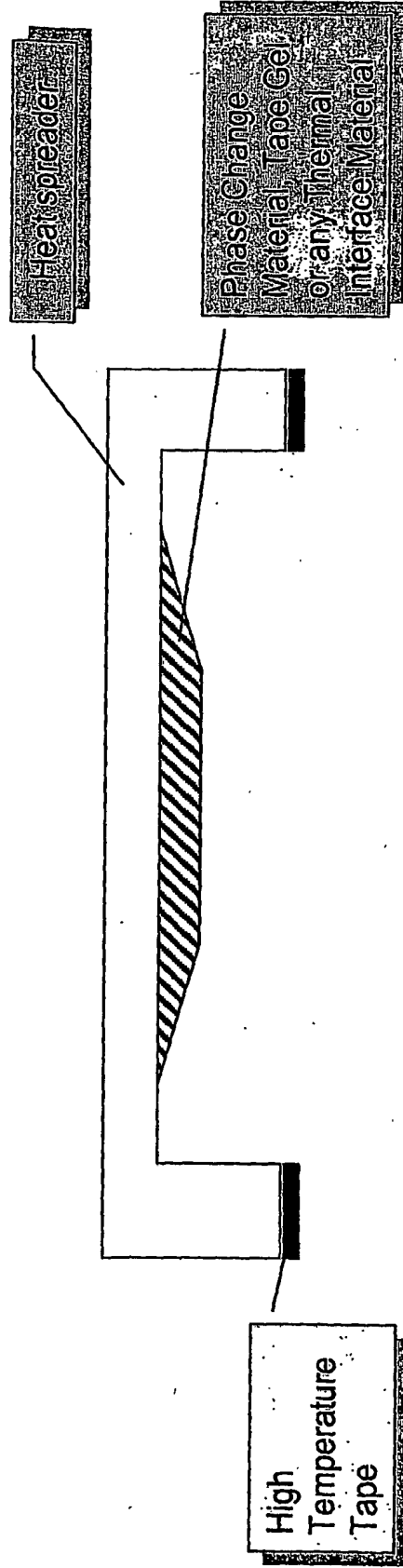
# IC Package with Combospreader Type 2



- i) Variety of adhesive tapes - 3M/Sony/etc.
- ii) Variety of tape thicknesses

Figure 19

# Combospreader Type 2



- i) Variety of adhesive tapes - 3M/Sony/etc.
- ii) Variety of tape thicknesses
- iii) Shape of heatspreader defined by

Figure 20

# IC Package with Combospreader Type 3

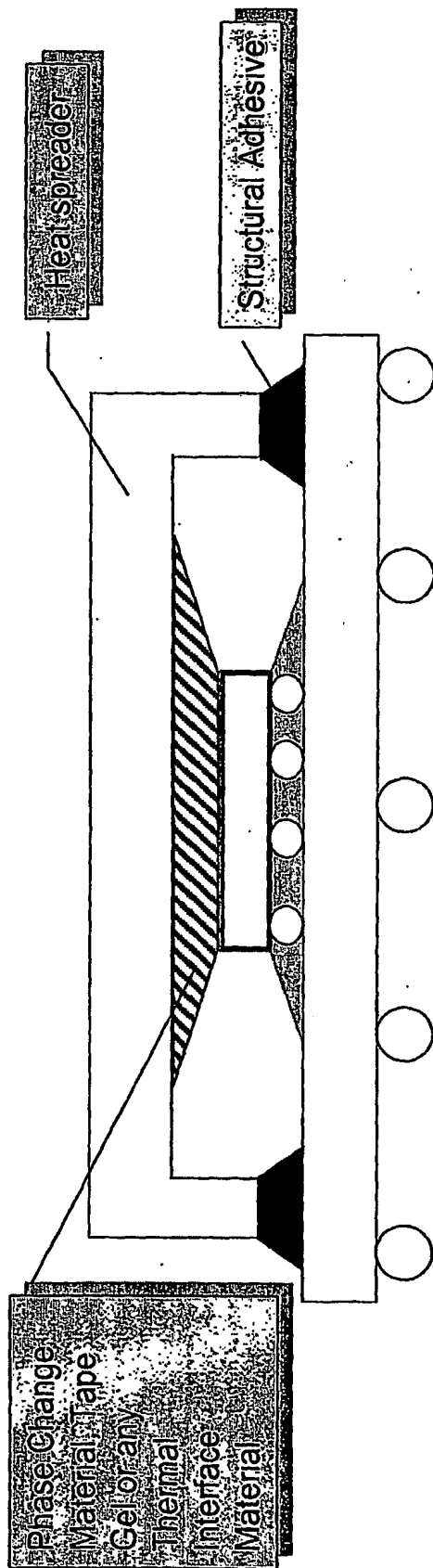
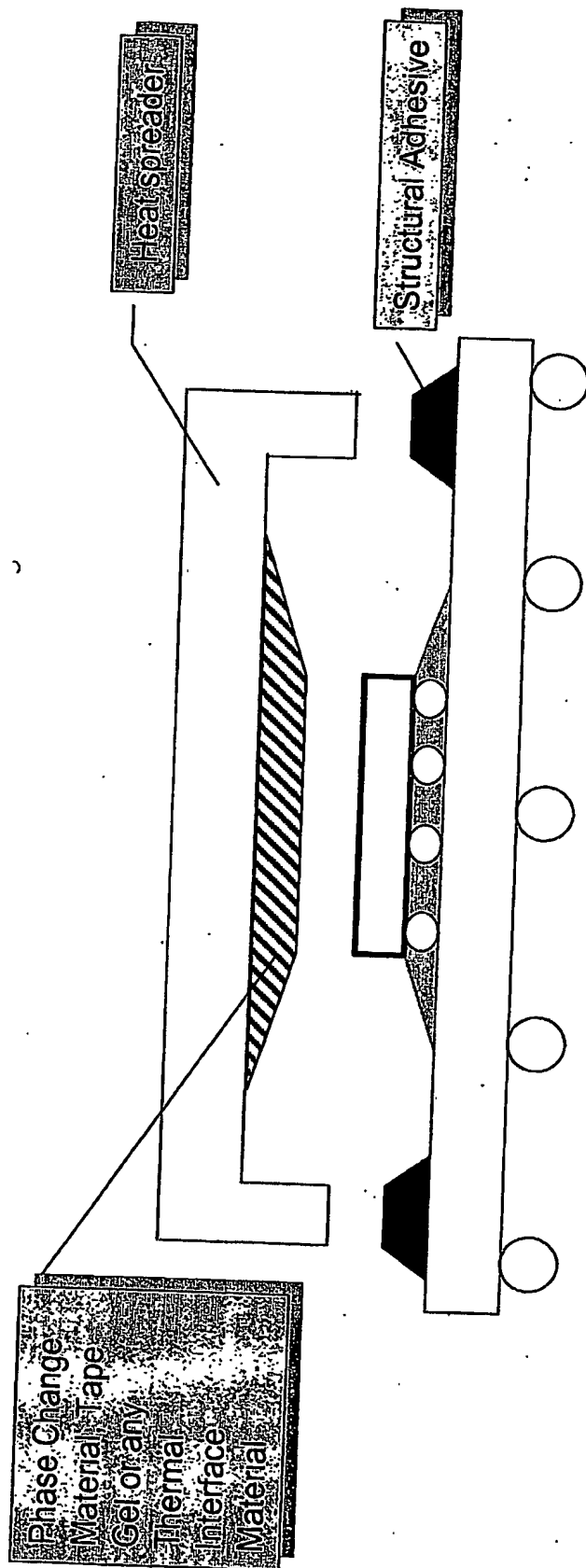


FIG. 1

FIG. 1

# Composreader Type 3



**SECRET**

FLUKE 22



# IC Package with Combospreader Type 4

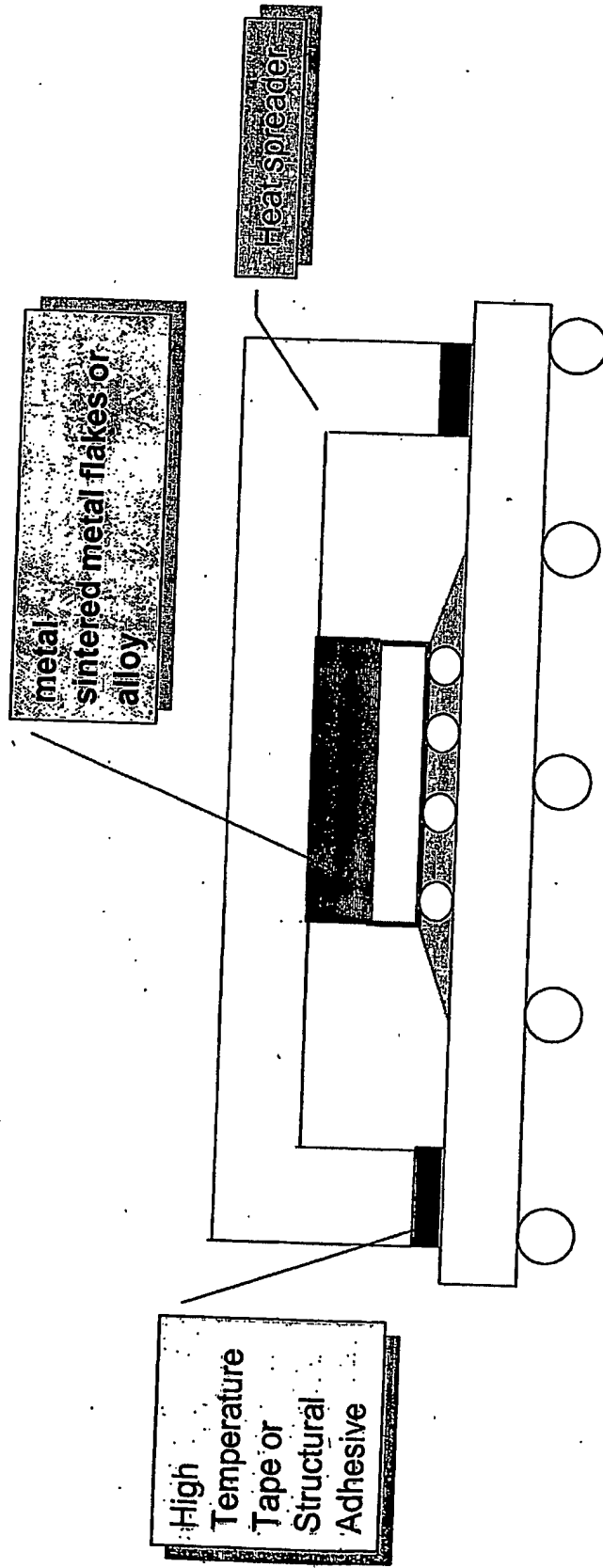
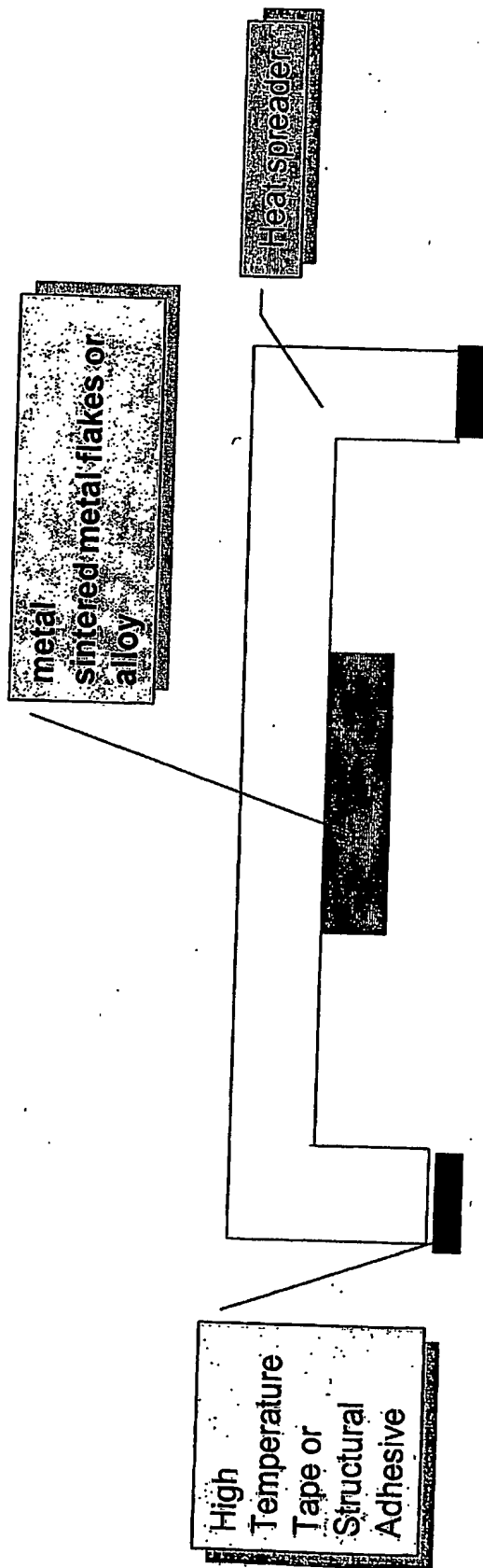


Figure 23

# Combospreader Type 4



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

FIGURE 24